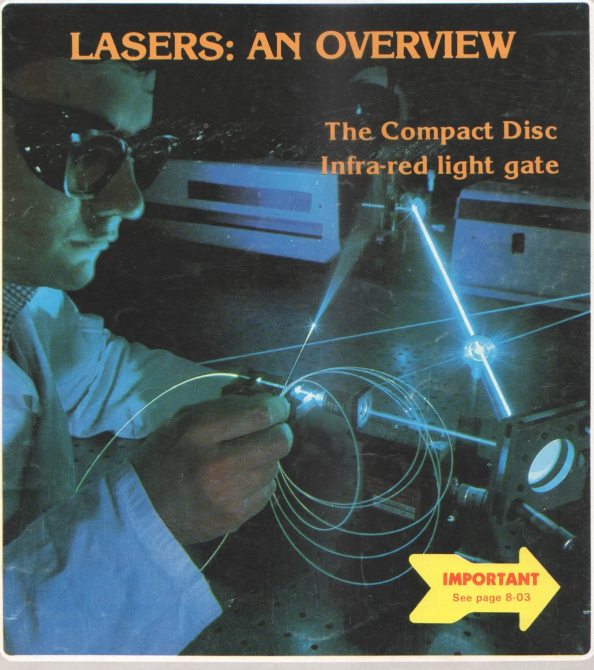
147

52
August
1987

elektor INDIA electronics

Rs. 7.50



LASERS: AN OVERVIEW

The Compact Disc

Infra-red light gate

IMPORTANT
See page 8-03

Publisher: C.R. Chandarana
Editor: Surendra Iyer
Editorial Assistance: Ashok Dongre
Circulation: J. Dhas
Advertising: B.M. Mehta
Production: C.N. Mithagari

Address:
ELEKTOR ELECTRONICS PVT. LTD.
52, C Proctor Road, Bombay-400 007 INDIA
Telex: (011) 76661 ELEK IN

Overseas editions:
Elektor Electronics
Standfast House Bath Place
High Street, Barnet Herts EN5 5XE U.K.
Editor:Len Seymour

Pulitron Publicacoes Tecnicas Ltda
Av Ipiranga 1100, 9° andar CEP01040 Sao Paulo — Brazil
Editor: Juliano Barsali

Elektor sarl
Route Nationale; Le Seau; B.P. 53
592270 Bailleul — France
Editors: D R S Meyer;
G C P Raedersdorf

Elektor Verlag GmbH
Susterfeld-StraBe 25 100 Aachen — West Germany
Editor: E J A Krempelsauer

Elektor EPE
Karaiskaki 14 16673 Voula — Athens — Greece
Editor: E Xanthoulis

Elektor B.V.
Peter Treckpoelstraat 2.4
6191 VK Beek — the Netherlands
Editor:P E L Kersemakers

Ferreira & Bento Lda
R.D. Estefania, 32.1° 1000 Lisboa — Portugal
Editor: Jorge Goncalves

Ingelek S.A.
Plaza Republica Ecuador 2-28016 Madrid-Spain
Editor: A M Ferrer

In Part:
Kedhorn Holdings PTY Ltd Cnr Fox Valley Road &
Kiogle Street Wahroonga NSW 2076 — Australia
Editor: Roger Harrison

Electronic Press AB
Box 63 182 11 Danderyd — Sweden
Editor: Bill Cedrum

Distribution/Subscription
For Singapore, Malaysia and Brunei
C.R. DASARATHA RAJ PRIVATE LIMITED
126, Race Course Road
Singapore - 0821 Tel. 2931422

MEMBER

Printed at : Trupti Offset: Bombay - 400 013
Ph. 4923261, 4921354

elektor electronics

Volume - 5 Number - 8
August - 1987

Electronics Technology

Projects

Information

Guide lines

Selex-26

Now there's an easy way to learn *Everything About*

8086 8088

With the Low Cost 8088 Trainer Kit From Dynalog.....

The MICROFRIEND-LC series from Dynalog is growing fast. After the unparalleled success of the two low cost kits based on 8085 and Z80, now comes the 16 bit MICROFRIEND-PC/LC. The low cost 8088 trainer kit you have been waiting for. It has the high performance 8088 CPU running at 5 MHz, 8K powerful FIRMWARE in ROM and 8K CMOS RAM for user programs. Other attractive features include-

■ Memory expansion. ■ 48 parallel I/O lines. ■ RS 232C Serial channel. ■ Audio cassette interface. ■ Three 16 bit timers. ■ Prioritised interrput handling. ■ 50 pin expansion Bus. ■ On board EPROM programmer. ■ 24 key multifunction keypad. ■ 8 digit seven segment display. ■ All standard functions and commands available through hex keypad as well as through serial monitor.

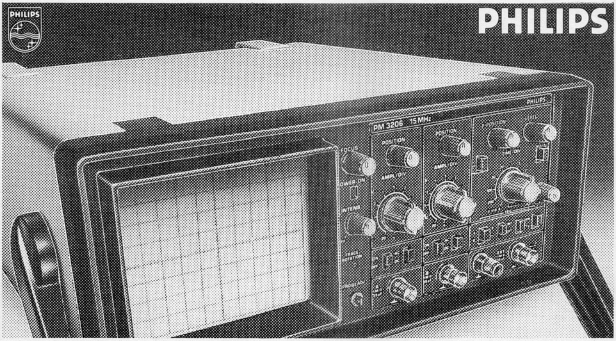
And the most attractive feature of the PC/LC is the built in software for interfacing the PC/LC with the IBM PC compatible computers, which means you can build up your own 8086/8088 development system after making an economical start with the PC/LC. Dynalog also supplies IBM PC, PC/XT, PC/AT compatible computers and peripherals.

For more details, write or call:

14, Hanuman Terrace
Tara Temple Lane
Lamington Road, Bombay 400 007
Tel: 362421, 353029
Tlx: 011-71801 DYNA IN
Gram: ELMADEVICE

DMS **Dynalog Micro-Systems**

ADDMark



Oscilloscopes so advanced, we even export them.

Philips PM 3206.
The 15 MHz oscilloscope

Fully developed at the totally integrated modern professional electronics factory in India, the PM 3206 is the latest oscilloscope from Philips, the largest manufacturer of oscilloscopes in the country today.

Now take a closer look at the PM 3206:

☐ Full 15 MHz Bandwidth with 5 mV sensitivity
☐ TV triggering for TV and Video applications
☐ External Z modulation facility
☐ Choice of triggering from A or B channels or externally
☐ International approvals like VDE & UL and local CIL tested
☐ Lightweight and portable
☐ Meets IEC environmental & endurance tests

To meet specific needs, the PM 3206 is available in four versions:

PM 3206/02: Dual trace and general purpose 'scope
PM 3206/LPT: (Long Persistance Trace) In DC and mains versions
PM 3206/60: Can operate from 24 V dc battery
PM 3206/RM: (Rack Mounting Type) Can also be used as a monitor.

However, the Philips PM 3206 is not the only 'scope that comes with the Philips performance/cost assurance.

The others in the range include the PM 3217 (50 MHz oscilloscope) and the PM 3262 (100 MHz oscilloscope)

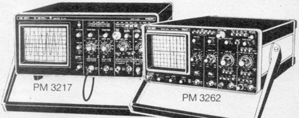
Every Philips oscilloscope incorporates state-of-the-art technology and advanced features that conform to international specifications and design standards.

Furthermore, they come fully backed by the nationwide service network of Philips. An assurance of prompt service anytime, anywhere in India.

For further information contact

Philips India
Industrial & Electro-Acoustics Systems Division
Calcutta: 7, Justice Chandra Madhab Road, Calcutta 700 020.
New Delhi: 68, Shivaji Marg, New Delhi 110 015.
Bombay: Band Box House, 254-D, A.B. Road, Worli, Bombay 400 025.
Madras: No. 3 Haddows Road, Madras 600 006.
Bangalore: 73/1, St. Mark's Road, Bangalore 560 001.

OBM/8829



Philips – the trusted Indian household name for over fifty years

MOBILE SATCOMS FOR THE FUTURE

by Dr John R. Norbury, Rutherford Appleton Laboratory

We have come to regard the geostationary satellite as the norm for communication between fixed stations and mobile stations such as ships and aircraft. Recent studies show the advantages of a highly elliptical orbit when planning satellite communications with land-based mobile stations, offering much better coverage at higher latitudes.

Nearly all recent proposals for satellite communications systems to provide a service to mobile stations have common features. They include the use of geostationary satellites, operating at radio frequencies around 900 MHz or 1.5 GHz; either low-gain omnidirectional antennas or higher-gain steerable directional antennas for the mobile terminals; and communication on narrow frequency bands which permits only a single channel to be carried on each allocated frequency (known as single channel per carrier, or SCPC, access techniques, which means restriction of data transmission rates to the low figure of some 16 kilobit s^{-1}).

Communication via geostationary satellites gives global coverage from a threesatellite constellation, which is ideal for most maritime and aeronautical applications, but it suffers from somewhat severe propagation problems when the line-of-sight path from the ground station to the satellite is at a moderate angle of elevation. This is especially so with land mobile satellite services (LMSS), where the low angle may lead to multipath propagation effects, attenuation by trees and blockage of the signal by buildings or uneven terrain. These factors place considerable constraints on the type of system that can be planned. For land mobile stations, there has to be a tolerance of fading of the signal power by a ratio of about 30:1, which in the communications engineer's parlance is a 15 dB (decibel) fading margin, to ensure a 90 per cent probability of acceptable speech communication over 90 per cent of the terrain covered in suburban and rural areas of North America.

Europe, with its more northerly situation and its mountainous terrain both in northern and southern regions, may need an even greater margin if there is to be a good enough service.

Cost considerations of land mobile stations call for simple, low-cost antennas; that in turn means the satellite should have a very large effective transmitter power to provide a service of commercial standard. This criterion could be met by using high-power transmitters and large satellite antennas, but only at a considerable penalty to the overall system cost.

The Molniya Orbit

An alternative to the geostationary orbit is the 12-hour Molniya orbit, used extensively by the Soviet Union and illustrated in the first diagram. It is a highly elliptical orbit which provides a satellite position giving angles near to that at zenith, when viewed from Earth at moderate latitudes, for eight hours of its orbit time. On alternate orbits it provides a further eight hours for a region at the same latitude but 180 degrees different in longitude. For 24-hour coverage over one region means using three satellites in three orbital planes separated by 120 degrees. Obviously, any such constellation of satellites also gives coverage for a region 180 degrees different in longitude from the originally planned region. Elevation angles for Europe and polar regions would be high, as is shown by the 'beam footprints' in the second diagram.

The left-hand part of the diagram shows the view of Earth from a satellite in a Molniya orbit with its apogee at 3.5°W. To the right is the view from the equivalent geostationary position. coverage of the polar region is seen to be excellent using the Molniya orbit, in contrast to that provided by geostationary orbit where the elevation angle to the satellite is zero at about 81 degrees North or South. This means that to provide complete polar coverage, even for fixed point-to-point communications services, satellites in non-geostationary orbits are needed.

1

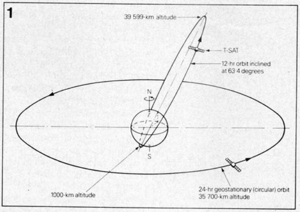


Fig. 1. The Molniya satellite orbit compared with the geostationary (circular) orbit.

Several satellite configurations are possible for LMSS, selected to reduce the overall power needed in the satellite and, thereby, the overall system cost. Constellations of satellites in low orbits have been proposed in the USA, and Canadian scientists have studied 12 and 24-hour elliptical orbits in detail. British studies, published by the UK Institution of Electrical Engineers, have investigated the application of Molniya orbits to provide UK coverage for LMSS. Such systems have several advantages for Europe. The elevation angles are greater than 60 degrees and there is the possibility of using high-gain non-steerable antennas for the mobile stations. Furthermore, the reduction of multipath propagation with such an orbit adds to these factors to remove many of the constraints imposed by a geostationary orbit system. It means the fading margin that has to be tolerated is reduced to a few decibels, and the gain of the mobile station antenna could be as high as 15 dB, so the link can be engineered taking into account a starting advantage of some 100 times more antenna-to-antenna power being available, from base station to mobile, than in the geostationary system. And, although it is necessary to provide a three-satellite constellation for coverage over 24 hours, the launch energy needed to place a satellite into a Molniya orbit is roughly half that for a geostationary equivalent.

2

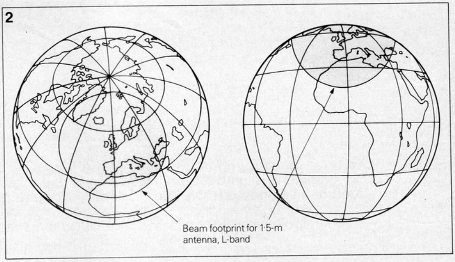


Fig. 2. Comparison of coverage by (left) a Molniya orbit and (right) a geostationary orbit.

The capital cost of a satellite system tends to be related directly to the amount of radio-frequency power needed for the link. So any configuration that reduces the power needed per voice channel, as in the case of the elliptical orbit satellite, makes the system a great deal more commercially attractive. The provider of a satellite mobile service would have the choice of an initial system of satellites working at relatively low radio-frequency power per voice channel, or have many more revenue-earning channels for the same capital cost as in a geostationary system.

Studies conducted recently in the UK favour a 12-hour elliptical orbit, because it would be the lowest cost option for a demonstration satellite. But the orbit does pass through the Van Allen radiation belts, which could degrade electronics devices and solar panels. A so-called Tundra orbit, taking 24 hours, enables this high radiation environment to be avoided. When deciding on the best orbit for an operational system, it will be necessary to compare the threesatellite Molniya constellation, using a low launch energy and small satellite antenna, with the two-satellite Tundra system where launch costs are higher, antennas are bigger but the radiation environment is better.

Transmission Frequencies

Procedures for allocating frequencies for radio systems are co-ordinated through the International Telecommunication Union (ITU). Radio transmissions do not respect national boundaries, so agreeing uses of the radio spectrum tends to be rather lengthy. A series of World Administrative Radio Conferences (WARC) are held at suitable intervals to agree international usage. However, at the last major conference, WARC 79, no part of the spectrum below 20 GHz was allocated to land mobile satellite services in the European region (Region 1), whereas a small allocation at UHF was allocated for use in the Americas (Region 2) and Asia (Region 3).

This lack of spectrum is a big stumbling block for any commercial satellite land mobile service. A special conference, WARC MOB 87, has been organised to take place during 1987 to tackle the problem. Several solutions seem possible, with frequency slots in the regions of 1.5 GHz, 2.5 GHz and 5 GHz being topics for discussion. Although the conference might be mainly devoted to considering geostationary systems, some attention will also be given to elliptical orbit systems.

Table

Members of a consortium of university-based and other laboratories taking part in the mobile payload study.

Member of consortium	Area of study
Bradford University	Mobile system/system design
King's College, London University	Microwave system
Surrey University	On-board processor/ system design
Loughborough University	Modulation/demodulation
Manchester University	Coding/decoding
Portsmouth Polytechnic	Doppler correction
Queen Mary College, London University	Antenna
Rutherford Appleton Laboratory	Co-ordination/ system concepts

Payload Study

For several years a university consortium in the UK, whose members are listed in the accompanying table and whose activities are co-ordinated by Rutherford Appleton Laboratory, has been studying advanced ideas for satellite communication systems under the banner of Communications Engineering Research Satellite (CERS). Two ideas that have generated considerable interest are the use of on-board processing of signals in satellite systems and the application of the Molniya orbit. This group is now in the middle of a two-year project in which an electronic model of a mobile payload with full on-board processing is being built.

The design of the proposed payload is outlined in the final diagram. A simple reflector of 1.5 m diameter is planned for the antenna, the necessary steering to point to Earth in a Molniya orbit to be achieved by manoeuvring the satellite. Depending on the data rate, a transmitter power of between 10 W and 20 W will be needed. Full demodulation and decoding of the received signals would be included, using a variety of schemes. There are several modulation schemes to be considered, including one in which the carrier is phase-shifted by the data keying process. Decoding would be possible for a variety of coding schemes. An on-board microprocessor would control an electronic buffer store to allow re-formatting of data and retransmission using modulation and coding schemes that would be independent of the up-link channel.

Access schemes for communication with the satellite are, first, time division multiplexing (TDM) on the down-link to mobile stations with time division multiple access (TDMA) on the return path from mobile station to satellite; second, TDM on the down-link to mobiles with SCPC on the up link. The payload, by using dual channels for each system of access, allows full duplex (simultaneous two-way) operation. Both up and down channels would operate in the L-band (1.5 to 1.6 GHz), with data rates of 64, 128, 256 or 512 kilobit s^{-1}.

The motion of the satellite in the Molniya orbit causes a doppler shift in the transmitted and received signals. It is intended to compensate for this on board the satellite by controlling the

3

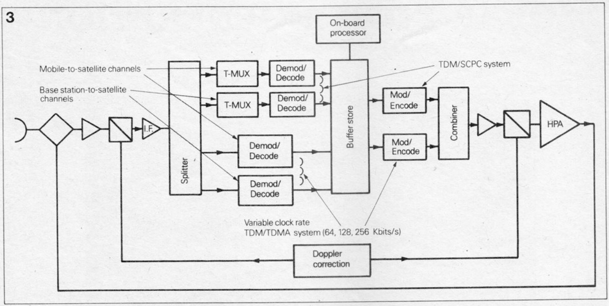


Fig. 3. Proposed scheme for the satellite-borne payload to be used for communication with mobile and base stations.

frequencies of its local oscillators, using either an on-board control system or ground control.

Different types of traffic such as short, coded messages or voice or facsimile could be accommodated within the same time frame merely by varying the length of the time slot allocated to each individual service by the multiplexing system. The full capacity of the system, using 4.8 kilobit s^{-1} voice coding would be about 50 voice channels.

For the mobile station, an antenna with an angle of ± 15 degrees could be used, mounted on the vehicle roof with its axis pointing vertically. Dimensions of less than one metre square are possible for this. The power of the mobile transmitter would need to be about 20 W. The only obstructions that may be expected to impair reception are overhead bridges or vegatation, or multipath scattering that might occur from very tall buildings. System coverage, in time and space, would be better than 99 per cent.

If the justification for satellite systems to provide communication with mobile stations is that they would fill in *all* the gaps not covered by a terrestrial-based cellular system, it might be questionable whether a geostationary service will be attractive enough commercially at such a level of coverage. An elliptical orbit system, although resorting to the complexity of operating a constellation of satellites, offers almost complete coverage even in urban areas and at greatly reduced signal strength requirement. Further spinoff might be found if these ideas were implemented in a European mobile system. The technology developed could equally well be applied to both mobile and fixed service systems for the equatorial regions of the Earth operating with a geostationary satellite. If this mobile satellite solution is commercially viable for Europe, then the cost of the transmitter-receiver, produced in quantity, would have to be comparable with those used in terrestrial mobile systems, namely of the order of £1000. The potential for such technology, in regions where satellite systems offer the most practical way of providing mass communication, seems considerable.

EW PRODUCTS • NEW PRODUCTS • NEW

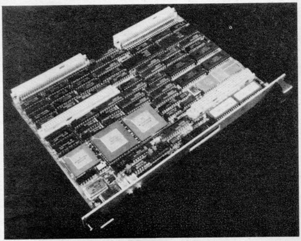
GMSVO7 single board computer

General Micro Systems GMSVO7 advanced single board computer is now available from UECS.

This high-performance CPU for the VMEbus provides ultra-high speed data movement, delivering the performance of a minicomputer at a fraction of the cost. Based on the 32-bit 68020 running at 20 MHz, it features up to 1Mbyte no-wait-state RAM, optional advanced memory management and high-speed floating point maths. A real-time clock calendar is standard. Mezzanine options provide VSB(MVMX32) compatibility, as well as a wide range of I/O possibilities. All system configuration is software-controlled, minimising the need for straps and jumpers.

Universal Engineering and Computing Systems Ltd
5-11 Tower Street
Newton
BIRMINGHAM B19 3UY
Telephone: (021) 359 1749

(3630-16F)



SOLAR POWER GENERATION

Research and development into the use of solar energy as an alternative source of energy have taken on new importance since the oil crises of the 1970s. Moreover, many of us are afraid of the spread of nuclear power stations, and all of us want to get rid of environmental pollution caused by oil or coal burning power stations.

The sun converts 600 million tons of hydrogen into helium through nuclear fusion every second, and in the process releases enough energy to meet our earthly needs for a million years. Of course, only a tiny part of the solar energy falls onto earth, which is readily seen when it is realized that the sun radiates equally in all directions. Since the average distance from the sun to the earth is near enough 150 million kilometres, the energy (in the form of electromagnetic radiation) takes about 8 minutes to reach the earth. In that time, the total energy radiated by the sun has spread over the inside of a sphere of surface area 3×10^{17} km². The total surface area of the earth that can be lit by the sun at any one time amounts to 113×10^{6} km². This means that only about 4 tenthousandmillionth parts of the totally radiated energy falls onto earth. The rest is lost in the universe.

The solar energy that reaches the earth can be converted into heat or electricity by various means, mainly solar collectors, magneto-hydro-dynamic (MHD) generators, and photovoltaic cells (normally called solar cells).

A major drawback to the widespread use of solar power generating systems is their high cost: at present, solar power costs £5-20 per watt as compared with a few pence for commercially produced electricity. On the other hand, solar power generation has a number of important advantages:

- Solar energy is free and in plentiful supply.
- Electricity can be generated, directly or indirectly, where it is needed, which in many cases would obviate the need for a distribution transmission line system.
- In the case of most solar power generating systems, there are no moving parts, which simplifies maintenance and enables unattended operation, for instance, solar cells on board satellites.
- It produces no waste or gases: it is clean.

Although the cost of solar power generation is at present such that it precludes the widespread adoption of solar power generating systems, it is expected that prices will fall dramatically over the next 10-15 years.

Solar collectors

Solar collectors are normally constructed in a way that allows the incident sunlight to be collected and converted into heat. The main types of collector are flat, concave, and heliostat. The flat type has the advantage of being able to operate from diffused light: the other two can only work from direct sunlight.

All solar collectors operate on the same basic principle: sunlight falls onto a blackened absorbent surface and heats the material immediately underneath that surface. The material is often water, but it can also be air—see Fig. 1. To protect the collectors from atmospheric effects and soiling, they are commonly covered by a sheet of Perspex.

Concave (parabolic) solar collectors are able to generate temperatures of up to 4,000 °C. They are usually constructed as a dish similar to satellite TV antennas.

Heliostat-type solar collectors make use of plane or concave mirrors that can be rotated (nowadays usually under computer control) to follow the sun across the sky—see Fig. 2. This type of collector affords efficiencies of up to 30%.

Solar collectors generally have good efficiencies and are getting cheaper. This is particularly so in the case of flat types, which are used more and more in the roofs of industrial buildings as well as in those of private houses—see Fig. 3.

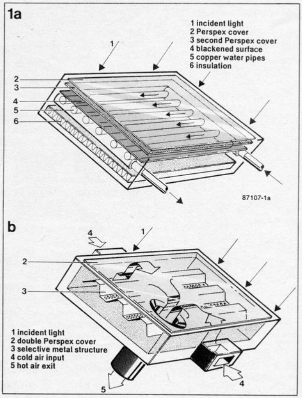


Fig. 1. Typical solar collectors operating with (a) water, and (b) air.

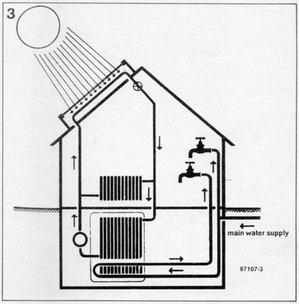


Fig. 3. Flat solar collectors installed in the roof of a private house.

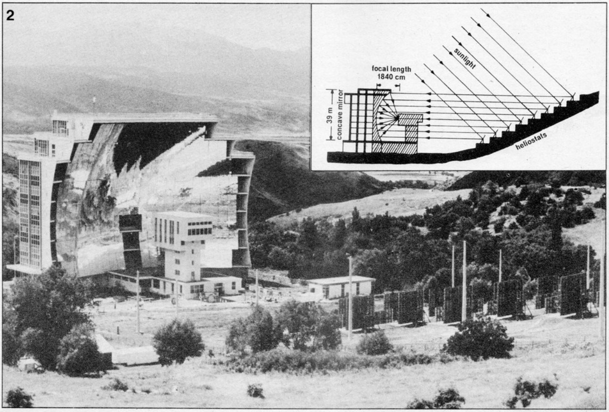


Fig. 2. The immense solar furnace at Odeillo in the French Pyrenees Mountains. The furnace uses a large number of heliostats, which deflect the sunlight onto a concave mirror. The total surface area of the heliostats is 2000 m²; the mirror is 39 m high and 54 m wide and its focal length is 18.4 m.

MHD generators

Magneto-hydro-dynamic generators convert thermal energy direct into electricity. A schematic representation of such a generator is shown in Fig. 4. The thermal energy is obtained by heating a gas to some 2500 °C by means of a large concave solar collector. When the temperature of the gas reaches 2500 °C, ionization occurs. This causes the gas molecules to accelerate to speeds of well over 300 m/s. The gas is then passed through a magnetic field, which separates electrons and ions, whereby an electric current is generated.
This type of generator is still in its infancy, although large prototypes are already in operation in the USA and the USSR. The main problem is the heating of the gas to the high temperature required. None the less, the prototypes work well and show efficiencies of up to 55%.

Solar cells

Solar cells provide an attractive and promising source of alternative energy. Unlike solar collectors, they provide a means of direct conversion of solar energy into electricity.

Types of solar cell

Crystalline silicon, Si. By far the largest proportion of solar cells currently manufactured are made from crystalline silicon. The basic construction of this type of cell is shown in Fig. 6. Its operation will be discussed later in this article.

Amorphous silicon, a-Si. Amorphous silicon is, according to many researchers, *the* solar cell material of the future, because its production costs are a fraction of the price of crystalline silicon.

Amorphous silicon can be formed by a number of methods, such as sputtering, pyrolysis, and high-frequency glow discharge. At present, the glow discharge method is preferred. In this, a substrate is held at a temperature of about 300 °C in a vessel in which the pressure is about 5 torr. Silicon hydrides, such as SiH_4 or Si_2H_6, or silicon tetrafluoride, SiF_4, are introduced into the vessel. When an HF voltage is applied, amorphous silicon begins to accumulate on the substrate. Doping of the a-Si is achieved by adding a phosphorus hydride, such as PH_3, for n-type, or a boron hydride, such as B_2H_6, for p-type.

4

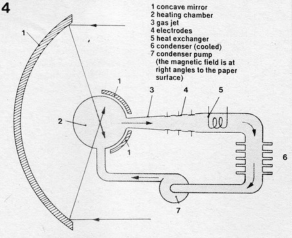


Fig. 4. Schematic representation of the magneto-hydro-dynamic generator used in the U02 plant in the USSR.

5

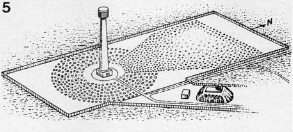


Fig. 5. Solar tower installation at Albuquerque in the USA. This type of installation is economically viable only where very large powers are required. It consists of a tower some 300 m high, around which plane or parabolic heliostats are grouped in circles. The mirrors beam the sunlight to the top of the tower where the solar collector is situated. The solar energy is converted into heat which is used to drive a large turbine.

6

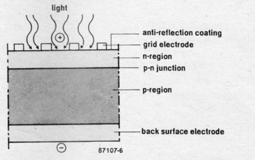


Fig. 6. Basic construction of silicon solar cell.

Table 1 Performance of various solar cells

Type of solar cell	Conversion efficiency (%)	Costs
Silicon		
monocrystalline	12	fairly high
polycrystalline	15	high
amorphous	8-10	very low
Copper(I)sulphide-Cadmium sulphide	7-9	high
Gallium-Arsenide	21	very high
Cadmium-Selenium	6-7	not known

Copper(I)sulphide-Cadmium sulphide, Cu_2SCdS. The electrical characteristics of this type of semiconductor are promising, although research into the material is still going on. From early prototypes, it is clear that both high efficiencies and high power outputs can be obtained.

Gallium-Arsenide, GaAs. Although this type of material affords a very high effciency, it is expensive to produce. However, it has a non-linear light-power characteristic, which makes it particularly interesting for use in combination with concave solar collectors. Moreover, compared with crystalline silicon, GaAs does not dissipate so much heat and, therefore, requires less cooling (smaller heat sinks).

Cadmium-Selenium, CdSe. This type of solar cell is still in the development stage.

Table 1 gives a comparison of these various types of solar cell. A number of other materials are actively being investigated in laboratories all over the world, but at present it does not look likely that these will find commercial application in this century.

Basic operation of a silicon solar cell

The characteristic behaviour of a semiconductor depends on the nature of the constituent atoms and on the way in which these atoms are grouped together. In other words, it is a function of the atomic structure as well as of the crystal structure of the semiconductor.
An atom consists of a positively charged nucleus surrounded by negatively charged electrons located in discrete orbits (shells) around the nucleus. Electrons can exist in stable orbits near the nucleus only for certain discrete values of energy, called energy levels of the atom. The allowed energies

7

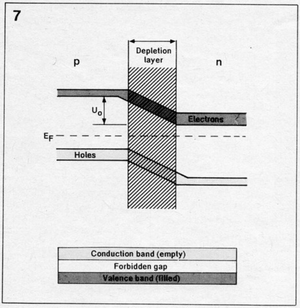


Fig. 7. Energy level diagram (simplified) of a semiconductor.

of electrons in an atom are represented by horizontal lines in the energy-level diagram shown in Fig. 7. Not more than two electrons can occupy a level: this results in electrons filling up the lowest possible levels first.

Since the atoms in a semiconductor are closely packed together, there are very many energy levels associated with each nucleus (because of the interaction between the atoms). This results in the energy-level diagram for the material becoming an energy-band diagram (each band contains very many levels).

The lowest energy band is called the valence band: this is filled with electrons, since there is an electron for each of the energy levels contained in the band. The upper energy band is virtually devoid of any electrons: it is called the conduction band. There is a small forbidden gap between the valence and conduction bands. Because of the thermal energy of the semiconductor at room temperature, some electrons can cross the forbidden gap into the conduction band. The consequent empty energy level in the valence band is called a hole.

The total current resulting from the electrons in a filled valence band is

$$j = nev = e\sum_{i=1}^{n} V_i = 0 \qquad [1]$$

where j is the current density, n the electron density, e the electron charge, and v the average velocity of electrons in the valence band.

If the kth electron crosses to the conduction band,

$$e\sum_{i=1,\, i\neq k}^{n} V_i = -ev_k \qquad [2]$$

from which it is seen that the vacancy (hole) in the valence band can be considered as a positively charged carrier fully analogous to the negatively charged kth electron. The velocity of the hole is equivalent to that of an electron in the same energy level.

At absolute zero, all the electrons occupy the lower energy levels, the valence band is filled to maximum energy, and no higher levels are occupied. This level of maximum energy is called the Fermi level, E_F, which is approximately constant with temperature. When the temperature is at room level, the electrons in a semiconductor are distributed between the valence band and the conduction band, and the Fermi level lies in the forbidden gap.

Since the Fermi level is constant throughout the silicon, the energy bands at the junctions in Fig. 8 are distorted, which causes an electric field accross the junction. This field is called the built-in field.

When the silicon p-n junction—see Fig. 8a—is in equilibrium (no bias), the cur-

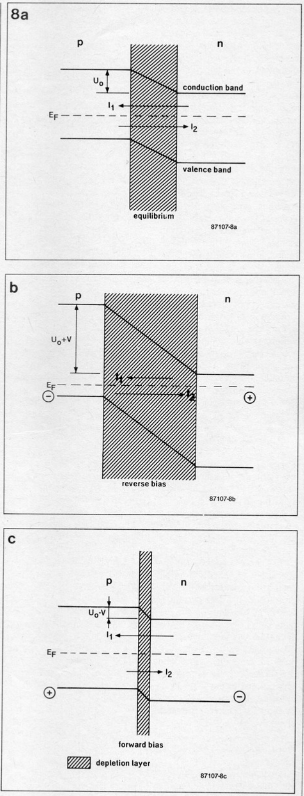


Fig. 8. Energy-band diagrams of a silicon p-n junction under different bias conditions. The net current across the junction depends on the strength of the built-in field, which is increased (b) under reverse bias, and reduced (c) under forward bias. The depletion layer is directly proportional to the built-in field. The built-in field, $E = U_o/x$, where U_o is the potential rise at the p-n junction due to small electron-hole pair movements in the semiconductor, and x is the width of the p-n junction.

rent I_1 resulting from electrons diffusing from the *n*-side is equal to the current I_2 which arises from electrons leaving the *p*-side. If a positive voltage is applied to the junction—see Fig. 8b—the built-in field is increased. The number of electrons diffusing from the *n*-region is then much smaller, since only few electrons have the energy required to overcome the built-in field. However, the number moving from the *p*-region to the *n*-region is not affected, because these electrons encounter no field. Therefore, a net current flows, but it is limited by the small number of electrons in the *p*-region. If the polarity of the applied voltage is reversed—see Fig. 8c—the built-in field is reduced and I_1 is large because the number of electrons in the *n*-region is so large. As before, I_2 from the *p*-region to the *n*-region remains unaffected. The net current is then large and corresponds to the forward direction.

The net current, I, under forward-bias conditions is given by the exponential expression

$$I = I_0\,[\exp(eV/nkT) - 1] \qquad [3]$$

where I_0 is the reverse saturation current, e is the electron charge, V the applied voltage, n a factor between 1 and 2 representing the deviation from ideal diode characteristics, k the Boltzman constant, and T the absolute temperature.

In a silicon solar cell, in the absence of incident light (called the dark state), the expression for the dark current, I_d is identical to that for I in formula [3].

When the cell is illuminated, a photo-generated current, I_{ph}, flows as junction reverse current. This current is directly proportional to the intensity of illumination. From Fig. 11 it will be seen that the net current, I, is given by $I = -I_{ph} + I_d =$

$$I = -I_{ph} + I_0[\exp(eV/nkT) - 1] \quad [4]$$

The voltage U_L across the load and the current I_L through it produce an output power P_o, which is equal to $U_L I_L$ or $I_L^2 R_L$, and is the direct result of the incident light falling onto the cell. Finally, Fig. 12 shows that the sensitivity of a silicon solar cell is greatest at a wavelength of about 0.8 μm, i.e., at the lower end of the band of visible light towards the infra-red region.

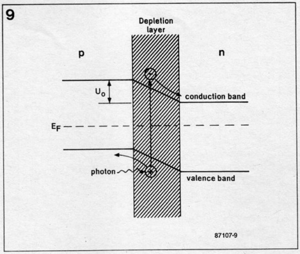


Fig. 9. Photovoltaic effect in unbiased p-n junction.

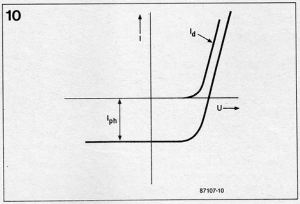


Fig. 10. Current-voltage characteristic of silicon solar cell.

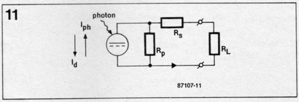


Fig. 11. Basic circuit of illuminated solar cell connected to load.

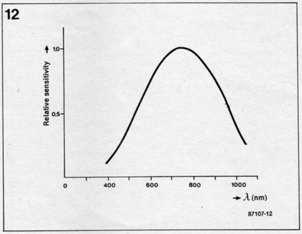


Fig. 12. Spectral response of a typical silicon solar cell.

References:

Physics of atoms and molecules by B. H. Bransden and C. J. Joachain

Quantum physics of atoms, molecules, solids, nuclei, and particles by Robert Eisberg and Robert Resnick

Die Technik der Solarzelle by Diaz Santanilla

LASERS: AN OVERVIEW

The development of lasers since they first appeared in the early 1960s has been spectacular. In just over 25 years they have become virtually indispensable in such diverse applications as compact disc players, fibre optic communications, surgery, and the Strategic Defence Initiative.

The first lasers appeared in 1960-61 when Javan, Bennett, and Herriott of Bell Telephone Laboratories announced the helium-neon laser just after Theodore Maiman, working at the Hughes Aircraft Corporation, had made a practical ruby laser. In little over a year later a semiconductor laser had been developed more or less simultaneously in Britain and the USA.

Foundations

An atom may be represented by a Bohr model: Fig. 1 shows that of a hydrogen atom. Bohr considered one electron of charge $-e$ and mass m, moving with speed v, and acceleration v^2/r in an orbit around a central nucleus of charge $+e$. In classical physics, charges undergoing acceleration emit radiation and would, therefore, lose energy. On this basis, the electron would spiral towards the nucleus and the atom would collapse. Bohr therefore suggested that in those orbits where the angular momentum is a multiple, n, of $h/2\pi$, the energy is constant. In the early 1920s, de Broglie proposed that an electron may be considered to behave as a wave of wavelength $\lambda = h/p$, where h is the **Planck constant** (4.14×10^{-15} eV s) and p is the momentum of the moving electron.

If the electron can behave as a wave, it must be possible to fit a whole number of wavelengths around the orbit. In that case, a standing wave pattern is set up and the energy in the wave is confined to the atom. If there are n waves in the orbit and λ is the wavelength,

$$n\lambda = 2\pi r$$

so that,

$$\lambda = 2\pi r/n = h/p = h/mv$$

from which,

$$mvr = nh/2\pi$$

This shows that mvr, the angular momentum of the electron is an nth multiple of $h/2\pi$.

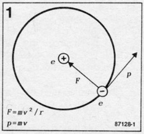


Fig. 1. Bohr's model of the hydrogen atom.

In Fig. 1, the electron moving around the nucleus has kinetic energy due to its motion and potential energy in the electrostatic field of the nuclear charge $+e$.

Bohr calculated the total energy E of the electron in terms of its charge, mass orbital radius, and the number n which quantizes the angular momentum. He then assumed that the electron can pass from one energy level to another. If, for instance, the electron jumps from energy level E_3, corresponding to $n = n_3$, to a lower level E_2, corresponding to $n = n_2$, the difference in energy is released as radiation of energy $h\nu$, where h is the Planck constant and ν is the frequency of the radiation. Therefore,

$$E_3 - E_2 = h\nu = hc/\lambda$$

where λ is the wavelength of the radiation and c is the speed of light in a vacuum.

Although Bohr's theory of the hydrogen atom was unable to predict the energy levels in atoms with many electrons, its fundamental ideas remain valid. For instance, the angular momentum of the electron has quantum values, and the energy levels of an atom have only discrete values: E_0, E_1, $E_2 \ldots E_\infty$; no other or intermediate energy level is possible. The lowest energy level, E_0, is called the **ground state energy**. All physical systems are in stable equilibrium in the lowest energy state.

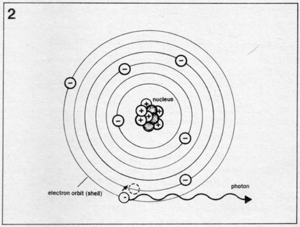


Fig. 2. Model of a many-electron atom. When an electron jumps to a lower energy level, a photon is released.

If an atom absorbs energy, and the energy of the atom reaches one of its discrete levels, E_1, the atom is said to be in an **excited state**. Once an atom has been excited to a higher energy level, E_n, it will try to reduce its energy. The energy lost if the atom reverts direct to the ground state is $E_n - E_0$. This energy is radiated in the form of electromagnetic radiation, i.e., quanta of energy $h\nu$—see Fig. 2. These quanta are called **photons**. The frequency of the photons lies in the range 5 nm to 10 μm. From the foregoing, it follows that

$$h\nu = E_n - E_0.$$

An atom can interact with a photon in three ways: **absorption, spontaneous emission, and stimulated emission**—see Fig. 3. If an atom absorbs a photon of energy $h\nu$, and the difference in energy levels of the atom is equal to $h\nu$, the

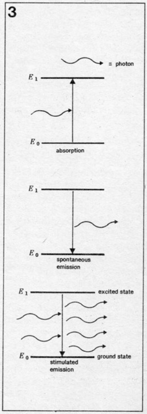


Fig. 3. An atom can interact with a photon in three ways.

photon will raise the atom to a higher energy level. In spontaneous emission, an atom in level 3 may of its own accord emit a photon $h\nu$, leaving the atom in the lower level 2. In stimulated emission, an atom in level 2 may be stimulated to emit a photon $h\nu$ by interaction with another photon of the same energy.

If in a system of atoms with an energy level E_n above the ground state there are no photons of energy $E_n - E_0$, where E_0 is the ground state energy, the atoms remain stable. If, however, a few photons of energy $E_n - E_0$ are introduced, these will immediately stimulate the emission of a number of photons of the same kind. This increases the number of photons in the system, which in turn stimulate the emission of more photons. In this way, an **avalanche effect** is produced, which results in all atoms in the system rapidly giving up their photons—see Fig. 4. This process is called **laser** action (**l**ight **a**mplification by **s**timulated **e**mission of **r**adiation).

In a system of atoms in thermal equilibrium, the number of atoms in the ground state is much greater than that in a higher energy state. This is called a **normal population** of atoms. In such a system at temperature T, the numbers, n_1 and n_2, of atoms in two successive states, E_1 and E_2, are related by the Boltzmann formula (in which k is the Boltzmann constant — 1.38×10^{-23} J K^{-1}):

$$n_2 = n_1 \exp[-(E_2 - E_1)/kT]$$

from which it is seen that at room temperature ($T = 300$ K), n_2 is considerably smaller than n_1, i.e., a normal population obtains. If it is possible to make $n_2 > n_1$, a **population inversion** is produced, which enables laser action to take place.

The output from a laser may be continuous (CW operation) as is usually the case with gas lasers, or pulsed as that from solid-state lasers. Table 1 lists a variety of lasers and some of their characteristics.

4

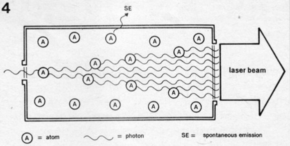


Fig. 4. Illustrating the avalanche effect if a photon or photons are introduced into a system of atoms.

Type of laser	Pressure	Efficiency	Power	Wavelength
He-Ne	0.1—25 mbar	0.01—0.5%	0.1—10 W	632.8 nm 1.15 μm 3.39 μm
CO_2	1.3 bar	10—30%	10—100 kW	9.6—10.6 μm
XE_2	30 bar	30%		200 nm
Dye		10—15%	0.1—10 W	
Cr^{3+}		1%	1000 W+	694.3 nm
Nd/YAG		1%	1—500 W	1.06 μm
GaAs			0.1—0.5 W (pulse: 1 kW+)	900 nm

Various lasers and some of their characteristics.

5

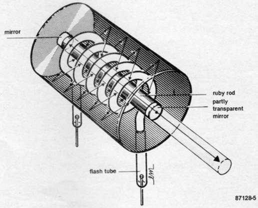


Fig. 5. Artist's impression of the construction of a ruby laser.

6

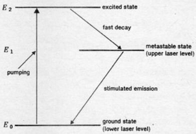


Fig. 6. Operation (simplified) of a three-level laser.

Three-level lasers

At present, the main solid-state lasers are the ruby (Cr^{3+}) and the neodymium/yttrium aluminium garnet (Nd/YAG) lasers. The ruby laser is a **three-level laser** ($E_2 > E_1 > E_0$), with a fast decay between levels 2 and 1, and a slow decay between 1 and 0. A typical construction of this type of laser is shown in Fig. 5.

Ruby consists of a small concentration of Cr^{3+} ions in a lattice of crystalline Al_2O_3. When a high potential is applied to the flash tube, the ions are excited, or pumped, by photons of wavelength 550 nm (green light) and energy $E_2 - E_0$—see Fig. 6. The excited ions decay spontaneously to the lower energy state E_1, emitting photons of energy $E_2 - E_1$.

The energy state E_1 has the special property of having a large stimulated emission probability and a low spontaneous emission probability. It is, therefore, filled with a far greater number of ions than the ground state E_0. There is thus a population inversion between these two levels, so that laser action can be initiated, resulting in the emission of red light ($\lambda = 694.3$ nm).

Four-level lasers

Except in a few cases, such as in the ruby laser, it is difficult to produce a population inversion between a ground state and an excited state, because initially all the atoms are likely to be in the ground state, and more than half the atoms have to be pumped to level 2 before a population inversion can be achieved. An easier method is possible in a **four-level laser** in which a population inversion is created between two excited levels—see Fig. 7. Initially, all the atoms are in the ground state, E_0, and none in the excited states 1, 2, and 3 ($E_1 < E_2 < E_3$). Level 3 is chosen so that it has a fast decay to level 2, and pumping between levels 0 and 3 immediately produces a population inversion between levels 2 and 1. As level 2 begins to fill up by the stimulated emission at frequency $(E_2 - E_1)/h$, the population inversion will decrease. To minimize this effect, level 1 is chosen so that it has a fast decay to the ground state.

Gas lasers are examples of a multi-level system, which can be pumped by an electrical discharge rather than by incident radiation. An important model is the He-Ne laser, in which the

7

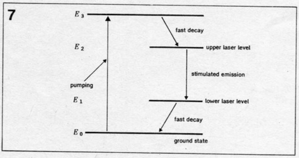


Fig. 7. Operation (simplified) of a four-level laser.

active material is a mixture of helium and neon gases contained at low pressure inside a long quartz tube with optically plane mirrors at each end—see Fig. 8. Two terminals near the ends of the tube enable a high potential to be applied to produce a discharge in the gas mixture. A typical construction of a He-Ne laser tube is shown in Fig. 9.

In an electrical discharge, the helium atoms are raised to the 2^1S and 2^3S levels which are metastable—see Fig. 10. By collision with these atoms, the neon atoms are excited to level 3, so that a population inversion is produced and laser action occurs as explained above. The wavelength of the emitted light depends on the reflectivity of the mirrors between which the gas is placed. Oscillation will take place at the wavelength for which this reflectivity is a maximum. In Fig. 10 it is—typically—633 nm (red light). It is seen that two other beams are also generated: one at 3.39 μm and one at 1.15 μm, but these are effectively suppressed by filter action of the mirrors.

Polarization of laser light

Although laser light is **coherent**, because all the photons (or waves) are in phase, polarization is random—see Fig. 11. To linearize the polarization, a Brewster window as shown in Fig. 9 is used. Such a window is a disk of plane glass (see Fig. 8) which is set at the Brewster angle to the incident light to ensure that only light of a given wavelength is passed.

Brewster's law states that when light strikes a glass surface at an angle of incidence given by $\tan^{-1}(n)$, where n is the refractive index, the reflected light is plane polarized. At this angle of incidence, the refracted ray makes an angle of 90° with the reflected ray.

Resonance cavity

The laser emitter is placed between parallel mirrors so that photons can be reflected back and forth many times, resulting in the build-up of a large photon density by the avalanche effect. It is, of course, necessary that one of the mirrors be partly transparent, so that some of the light can get outside the tube used.

The mirrors may be plane or curved as shown in Fig. 12. When plane mirrors are used, part of the emission may be reflected spuriously outside the system. Such losses must be kept small: reflections must be higher than 99%. When confocal mirrors are used, the beam is kept exactly parallel within the cavity. The slight divergence at the exit is controlled by a collimating lens.

Beam spread

Many laser tubes are marked with their internal beam radius, r_{bi}, from which the beam diameter, D_x, at a distance m can be calculated:

$$D_x=2\theta m$$

where 2θ, the angle of spread, is equal to $\lambda/\pi r_{bi}$: λ is the wavelength of the laser light.

If, for instance, a He-Ne laser, operating at a wavelength of 633 nm, has an internal beam radius of 0.375 mm, the beam diameter at a distance of 100 m is

$$D_{100}=2\theta m=2m\lambda/\pi r_{bi}$$

$$=2\times100\times633\times10^{-9}/3.142\times375\times10^{-6}=107.5 \text{ mm.}$$

Lasers and their applications

Since the development of lasers continues at a spectacular speed, only an outline of the state of the art will be given.

He-Ne lasers, because of their small output (0.1—10 mW) are best suited to use in laboratories and measurement techniques, but are also used for medical purposes. Their wavelengths are 632.8 nm, 1.15 μm, and 3.39 μm.

Argon-ion lasers, with outputs of up to 15 W, are frequently used in medicine for photo coagulation. Their bluish green light (488 nm and 514.5 nm) is selectively absorbed by haemoglobin and melanin. Their main application, however, lies in the field of eye surgery.

Carbon-dioxide (CO_2) lasers, operating in the infra-red

8

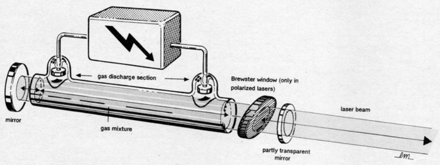


Fig. 8. Artist's impression of the construction of a He-Ne laser.

9

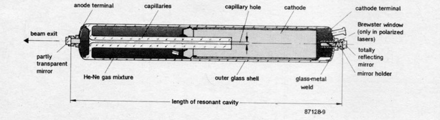


Fig. 9. Cross-sectional view of a He-Ne laser (courtesy of Siemens).

10

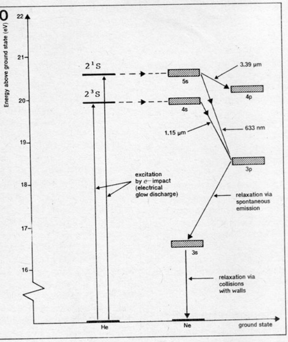


Fig. 10. Schematic representation of the operation of a He-Ne laser. The capital letter S is a code associated with the value of the total electronic orbital angular momentum quantum number *L*. The lower case letters s and p are used in the so-called spectroscopic notation, in which the value of the orbital angular momentum quantum number *L* is indicated. The superscripts to the left of the S give the value of 2S+1, or multiplicity, which is equal to 1 for singlet (S=0) states, and 3 for triplet (S=1) energy states.

13

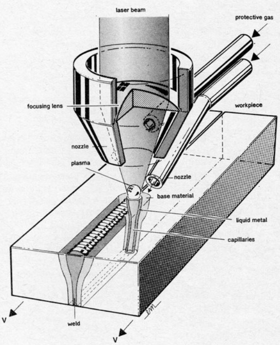


Fig. 13. Illustrating the operation of a CO_2 laser in industrial welding.

11

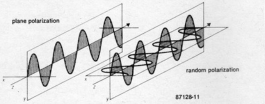


Fig. 11. Light may be randomly polarized, but in a number of laser applications it is required to be linearly polarized.

region (9.6—10.6 µm), are primarily used in industrial applications: hardening; drilling; welding; refining; and ageing are but a few of these. The use of a CO_2 laser for industrial welding is illustrated in Fig. 13.

The dye laser is pulse operated and pumped by a xenon flash tube—see Fig. 14—or by a pulsed beam from another laser. Continuous tuning of this type of laser is possible by making the grating that forms one end of the resonant cavity rotatable. With its very narrow line width and large frequency range, the dye laser is eminently suitable for use in spectroscopy and in the chemical industry.

Solid-state lasers find almost universal application in measurement techniques, be it the exact distance from the earth to the moon or the speed of motor vehicles. Many of these techniques are by-products of military research.

The only solid-state laser to be used in the medical world is the **Nd/YAG laser.** Because of its high power output (>100 W continuous) and operation in the infra-red region (0.9—1.35 µm), this type of laser is particularly suitable for operations in soft tissues, such as the removal of tumors in the oesophagus.

Solid-state lasers can produce pulses of extremely high power: a power of 100 TW (=10^{14} W!) at the peak of a 2 ns pulse has been reported. Such enormous powers are needed in the strategic defence in-

12

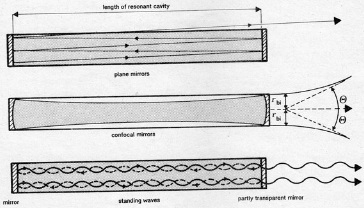


Fig. 12. It is essential that standing waves are generated between the mirrors terminating the resonant cavity. The shape of the mirrors has an effect on the efficiency of the laser.

14

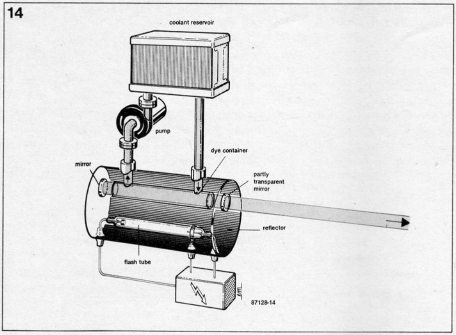


Fig. 14. Artist's impression of a dye laser.

15

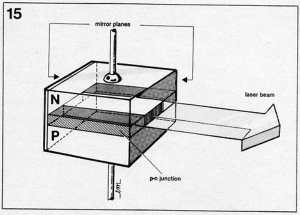


Fig. 15. Semiconductor (GaAs diode) laser.

16

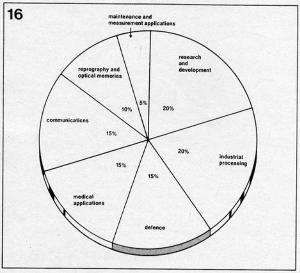


Fig. 16. Division of the world market for lasers in 1986.

itiative and in research into nuclear fusion. The exit beam diameter of such lasers is artificially increased to about 1 m to prevent vaporization of the lenses.

By far the most common lasers nowadays are **semiconductor or injection lasers**. These lasers are based on the fact that a population inversion of electrons can be achieved by applying a voltage across the p-n junction of doped gallium-arsenide (GaAs) material. Semiconductor lasers are available for operation from the near ultraviolet to well into the infrared regions. An artist's impression of the construction of a GaAs laser is shown in Fig. 15.

Semiconductor lasers are of prime importance in modern communications, optical memories, and in compact disc players. In fibre optic communications, for instance, they enable transmission rates of 1400 Mbit/s to be achieved. Without the small dimensions of the diode laser, it would not have been possible to develop the compact disc player. A very recent development based on the diode laser is compact disc video.

In the fore-front of laser development is the **excimer laser** which uses diatomic rare-gas hallides as the active material. This type of laser was described in the March 1987 issue of *Elektor India*.

Commercial considerations

In 1986, the world market for lasers amounted to more than £425 million. The largest sectors were research and development, and materials processing —see Fig. 16. When studying this figure, it should be borne in mind that the diode laser for a CD player costs only about £3, whereas an industrial model may cost as much as £30,000. It is expected that the laser market will have grown to around £1,000 million by the early 1990s.

References:

Advanced level physics by
M. Nelkon and P. Parker

Optics and its uses by
G. F. Lothian

Physics of atoms and molecules
by B. H. Bransden and
C. J. Joachain

Quantum physics of atoms, molecules, solids, nuclei, and particles by Robert Eisberg
and Robert Resnick

Physics by David Halliday
and Robert Resnick

Fundamental University Physics
by Marcelo Alonso and
Edward J. Finn

THE COMPACT DISC

In the mid-1970s, engineers at the Dutch electronics company Philips felt they had developed just what the world had been waiting for. They called it the Laser-Vision videodisc. This is an optically scanned disc which gives an hour of colour video and sound. Unfortunately for Philips, the video disc arrived too late: too many people already had a video cassette recorder. Undismayed, the engineers continued their development, and in early 1979 Philips unveiled a trimmed down version of the videodisc, much smaller and containing sound only. It was called the compact disc.

Because of the very favourable reception of the compact disc system, Philips felt it had a new world standard to replace the conventional (and vulnerable) gramophone record. Wisely, it came to a joint agreement with Sony to perfect the system.

The first compact disc player went on sale in Japan in late 1982, and in Britain six months later. At that time, a player cost around £500 and the discs about £10. Now, just over four and a half years later, a reasonably good player can be bought for under £200, and it is expected that prices will be under £100 by Christmas. The discs have, however, risen slightly in price to about £12-14.

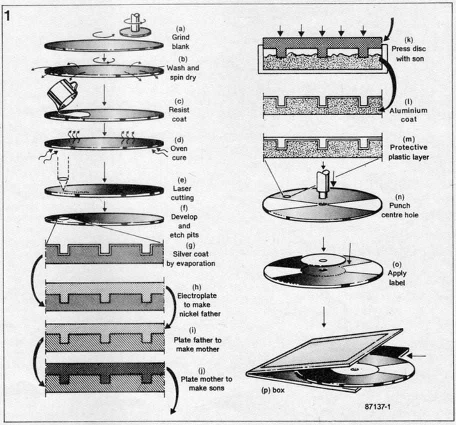


Fig. 1. Some of the stages in the production of a compact disc.

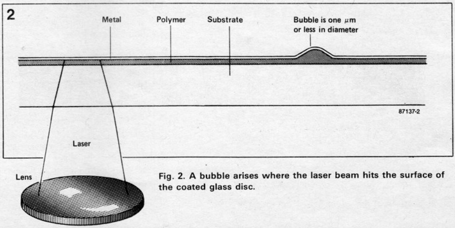


Fig. 2. A bubble arises where the laser beam hits the surface of the coated glass disc.

Production technique

The master (or blank) is made of a glass disc that is ground and polished to optical flatness—see Fig. 1. This is coated with a layer of photoresist, the thickness of which is controlled very accurately. The coating is oven-cured, after which the disc is ready for cutting. Strictly speaking, the term "cutting" is incorrect, because the recording is created photographically, but because of some parallels with the production of a vinyl gramophone record, it has been retained.

Cutting is carried out by a continuously operating helium-neon (HeNe) laser, which is intensity-modulated by the audio signal via an acoustic modulator. In the absence of an audio signal, light can pass through the modulator, but with an audio input light is scattered. The laser travels from the centre of the disc to the outer as the master revolves. The rota-

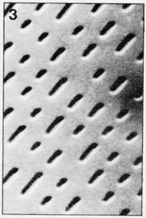


Fig. 3. The surface of the master after the developing and etching process.

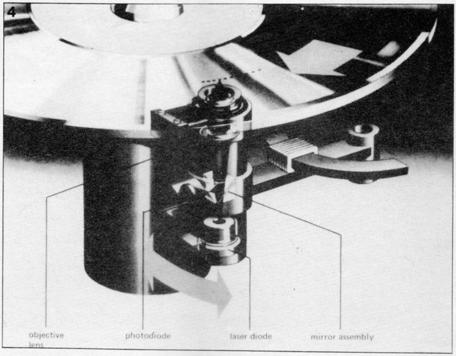


Fig. 4. Typical construction of a laser pick-up unit.

tional speed of the disc is reduced gradually in a way to ensure that the speed of the laser beam over the surface of the blank remains constant.

The photoresist is then developed during which the unexposed areas are hardened. Subsequent etching removes the exposed areas, which has the effect of creating pits in the surface of the resist as shown in Fig. 3. These pits represent the digital information of the audio input.

The disc is then given a thin silver coating to make it electrically conductive. At this stage, it would be possible to produce a commercial compact disc from the master. However, to preserve the master, only a few (negative) copies, called "father" are made. From these, a number of (positive) intermediate copies, called "mother" are made, and these in turn produce a number of "sons" (negative). The sons are the dies used to stamp compact discs. Since there are an even number of processes, the compact disc is identical to the master.

The compact disc is made of 1.2 mm thick polymethylmethacrylite, better known as Perspex, or of Makrolon, a polycarbonate plastic. The surface of the side of the CD that contains the audio information is then given a thin layer of aluminium, followed by a protective coating of laquer. The thickness of the aluminium layer is of the order of only 10 nm, while that of the laquer is about 5–10 μm. This side of the disc is called the label side, because the identifying label is printed or affixed here.

The information is read from the disc by a laser at the underside, i.e., through the Perspex or Makrolon. The laser, therefore, sees the pits as bumps. A typical construction of a laser pick-up unit is shown in Fig. 4.

Structure of the compact disc

Figure 5 gives a cross-sectional view of a compact disc. The lead-in track contains all the necessary information regarding the recorded music or speech. A total of some 20,000 tracks are contained within the 33 mm wide recording surface. The digital data are defined by the length of the pits and the distance between them. The length of the pits varies from 833 nm to 3.56 μm, their width is 500 nm, and their depth is 110 nm. The distance between two adjacent tracks is 1.6 μm. The disc contains some 7×10^9 bits. At a constant linear velocity—CLV—of $1.2\ \mathrm{ms}^{-1}$, the maximum playback time is 74 minutes.

The Perspex from which the disc base is made has a refractive index, n, of 1.46. The diameter of the laser beam when it enters the Perspex is 0.8 mm, but because of refraction this is reduced to 1.7 μm at the recording surface—see

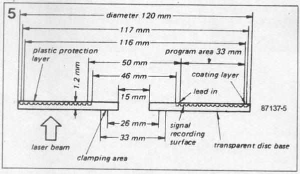


Fig. 5. Structure of a compact disc.

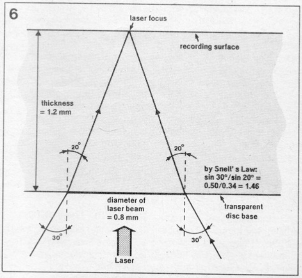


Fig. 6. How the laser beam is focused onto the recording surface.

Fig. 6. This small diameter is one of the reasons that, say, a dust particle of 0.5 mm does not affect the reproduction of the disc.

Pits and bits

The pits and the reflective (aluminium) surface represent logic 0s and 1s respectively. When the laser beam is focused on a pit, ideally no light should be reflected. To achieve that, the depth of the pit, a, is approximately equal to $\lambda/4n$, where λ is the wavelength of the laser light and n is the refractive index of the disc base.

Since the diameter of the laser beam at the recording surface is $1.7\ \mu m$, and the width of a pit is $0.5\ \mu m$, some light is reflected from the pit. Because of the relationship between the depth of the pit and the wavelength of the laser light, there will be a phase difference between light reflected from a pit and that reflected from the aluminium layer of $2\lambda/4 = 180°$ (in an ideal case). This means that due to the interference effect the two reflected light beams will cancel one another. In practice, this cancellation will not be complete, however, but the reduction in the total reflected light is none the less sufficient to actuate the focusing detector unit. The reflected light is consequently modulated in a manner that depends on the length of the pit.

The optical system

The laser, optical system, and detector are contained in one unit as shown in Fig. 7. The collection and telescope lens assemblies focus the light emanating from the laser diode. The correction prisms shape this to an annular beam. This beam is deflected by a routeing mirror assembly to a polarizing beamsplitter and $\lambda/4$ plate assembly, where the plane of polarization is shifted by 90°. From there, the beam passes through the objective lens to the recording surface of the CD. The reflected light is taken from the objective lens, aligned parallel, and then falls onto the $\lambda/4$ plate. The plane of polarization is again shifted 90°, after which the beamsplitter directs the beam to the focus error prism, from where it travels to the detector (photo-sensor).

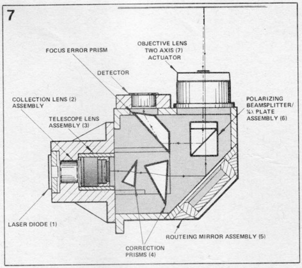


Fig. 7. Cross-sectional view of a typical laser pick-up unit.

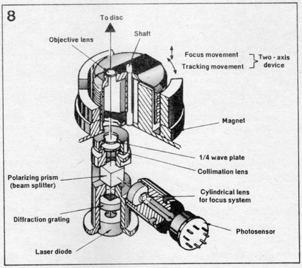


Fig. 8. The SONY laser pick-up unit.

In the Sony laser head used in commercial CD players, shown in Fig. 8, the photo-sensor is a four-quadrant type. This head contains two extra sensors (E and F) for the side spots. Control signals from these sensors drive the two-axis device.

Input signals for the audio amplifiers, servo systems, and associated circuits in the compact disc player are also taken from the photo-sensor unit.

Sampling frequency

The sampling frequency should be greater than twice the frequency of the highest audio frequency the system is required to process. Taking also the anti-aliasing requirement into account, a world-wide standard of 44.1 kHz was chosen.

With a sampling frequency of 44.1 kHz, the upper audio frequency range must be limited to just above 20 kHz. Although this is considered satisfactory by many, there are also many who feel that this limitation is unacceptable. Since manufacturers of CD players can not change the agreed sampling frequency, they have developed a technique called digital filtering or oversampling.

In oversampling, the original sampling frequency is seemingly doubled or even quadrupled by electronic means. In twice oversampling, there are 44,100 real samples coming off the disc, and a special electronic circuit adds a sample between each pair of real ones to give a total of 88,200 samples. These added samples are an electronic prediction as to what they would have been had they been recorded on the disc.

In four times oversampling, the number of predicted samples increases to three between each pair of real ones. In some CD players, the previous thirty samples are used to predict every set of three guessed samples.

With all oversampling, extra bits are generated: one in twice oversampling, and two in four times oversampling. These bits are in addition to the 16 bits already coming from the disc. Unfortunately, the signal processing circuits of CD players can cope with 16 bits only, so that, ironically, some of the information has to be discarded.

Although CDs are fully protected from dust and soiling, it is, none the less, necessary to clean them from time to time. One of the best ways to do this is with the BIB Compact Disc Cleaner kit. The kit contains a foam-lined moulded tray in which the CD is held, cleaning fluid, a soft brush to remove dust, a felt cleaning pad, and a chamois leather to dry and polish the disc. Available from most audio retailers or direct from BIB Audio Video Products Ltd • Kelsey House • Wood Lane End • HEMEL HEMPSTEAD HP2 4RQ • telephone (0442) 61291.

Aliasing is a type of interference that occurs when the frequency of the signal to be sampled is equal to or greater than half the sampling frequency.

Disc production

At present, there are only a dozen or so CD producers in the western world and two in the USSR. Most of these made their name through gramophone record production and have been in existence for a long time.

The largest CD producer is currently PolyGram, a subsidiary of Philips, with plants in Federal Germany and Britain. The first British company to produce CDs was Nimbus of Monmouth, which started in 1984. There is now also Thorn-EMI in Swindon. Since worldwide production at present amounts to only about 100 million per year, it is clear that with nearly 20 million CD players in use in the western world demand outstrips supply, which will keep the price of the disc high. It will take a year or so yet before supply will start catching up with demand: only then is there a likelihood of CD prices coming down from their present level.

The biggest bottleneck in production is the metallization of the disc with aluminium which ensures that the disc can be read by the laser in the player. Until recently, this was done in large chambers that hold hundreds of discs at a time. It takes about 15 minutes to create a vacuum in the chamber and another 10 minutes to deposit the aluminium. New machines from Balzer in Switzerland bring the cycling time down by more than a half. These evaporation chambers are held at a permanent vacuum. The discs are loaded at one end on a conveyor and passed through a series of bulkheads that create a pressure gradient from atmospheric to high vacuum and up to atmospheric again.

In spite of the strict clean-room procedures at CD production plants (in most the disc does not come into contact with humans until it has been given the protective lacquer coating: all previous operations are performed by robots), the rejection rate remains high at over 10% over the entire production process. It should, of course, be realized that this involves no fewer than 60 stages from tape mastering, through disc mastering, electroplating, pressing, metallization, and so on, to packaging.

An interesting aspect of the siting of a CD production plant is that the foundations must be very stable: deep rock is preferred, because its natural movement is not more than a few micrometres at very low frequency. This stability requirement becomes clear when it is realized that the track dimensions of the high density master discs are less than 1 micrometre.

The CD video

During the preparation of this article, Philips, Sony, and a number of other Japanese manufacturers announced the CDV player. This type of player, whose commercial launch is planned for the coming autumn, can handle normal audio compact discs as well as the new CDV discs which hold 5 minutes of colour video as well as 20 minutes of sound only.

It appears these manufacturers' intention to use CDV as a means of marketing pop music video clips. Polygram, Philips' subsidiary record, CD, and tape manufacturing plant in Federal Germany, is in full support of the new system, and claims that most of the world's large record companies have confirmed their backing.

The video picture signal is recorded towards the outer edge of the disc, where it is easier to get a high tracking speed. Normally, a digital audio disc spins between 196 and 486 rev/min to give a constant linear velocity (laser tracking speed) of 1.2 m/s. This is too slow even for analogue video.

The snag with the new system is that it is linked to TV standards, at least as far as the video section is concerned. For PAL CDV discs, with 25 pictures/s, the rotational speed varies from 1512 to 2250 rev/min, giving it a CLV of between 9.2 and 10.2 m/s. For NTSC video (30 pictures/s), the spinning speed will be 1815 to 2700 rev/min, resulting in a laser tracking speed of between 11 and 12 m/s.

Commercial aspects

During the 1980s, the audio equipment market in general grew moderately in size, but hardly at all in value. The exception was the CD player sector, which saw a boom towards the end of last year that continued into this year. An estimated 192,000 players were sold in November and December alone: a three-fold increase compared with the same months in 1985. If these new buyers follow their predecessors' purchasing patterns, the sale of CDs should rise quite sharply. Gramophone Magazine's CD survey showed that 69% of CD player owners own more than 20 discs. However, although compact discs offer hitherto unattainable quality, at nearly twice the price of LPs and cassettes they still appeal mainly to the serious music enthusiast.

Figures just released by the British Radio & Electronic Equipment Manufacturers' Association (see Table) show that during last year CD player deliveries were at more than four times the level achieved in 1985. The major development in 1986 was the increasing availability of combination products, primarily CD music centres, which contributed to a high level of consumer interest. These products accounted for over one tenth of total music centre deliveries. The CD separates sector was very active and registered a more than three-fold increase over the 1985 results. These represent faster growth than that achieved by any other consumer electronics product.

Table 1

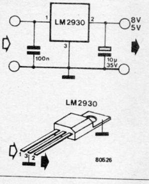
	Separates		Combinations		Total Deliveries	
	1985	1986	1985	1986	1985	1986
Q1	16	64		8	16	72
Q2	20	96		24	20	120
Q3	33	158		64	33	222
Q4	78	165		60	78	225
	147	483	N/A	156	147	639

The figures show quantities in thousands.

---

car stabiliser

Together with the 'ordinary' three pin regulator IC's a few different types for special use are becoming available. The LM 2930 from National was primarily intended for use in the car, but it also has other applications. The IC has a few quite useful characteristics, such as the fact that the difference between input and output voltage need only be 0.6 V. Changing the input voltage's polarity is no longer a disaster and short voltage peaks of up to 40 volts cause no damage. Other characteristics include voltage limitation and thermal protection and although useful, are less spectacular.



Since the output voltage is 5 volts (there is also an 8 volt version) and the maximum current is 200 mA, this regulator will be ideal for use with instruments (speedometers, computers) rather than in audio.

The circuit is extremely simple. Both capacitors have to be mounted close to the IC in order to prevent oscillation. In most applications the IC must be mounted on a heatsink; this can be connected to ground. The maximum input voltage is 26 V. ◼

FILTERS: THEORY AND PRACTICE — 1

by A.B. Bradshaw

The design of filters remains a topic of considerable interest to practitioners in many branches of electronics, in spite of the fact that many of such networks can nowadays be purchased at relatively low prices. None the less, there are still many occasions when a filter has to be designed from scratch. This series of articles will look at the theory underlying such design, and in the last part two practical designs will be discussed in detail.

As long as there has been elecronic engineering there has been a need for filters: low-pass, high-pass, band-pass, and band-stop. Basically, a filter is an electrical network that will pass signals with frequencies within certain ranges and suppress signals with other frequencies.

A network is essentially a number of impedances connected together to form a system the behaviour of which depends on the values of the resistances, capacitances, and inductances from which it is made up, and on the way in which they are interconnected.

In the 1920s, Zobel developed the so-called image parameter theory, which formed the foundation for filter and network design until comparatively recent times. This theory met the needs of designers working on filters for multi-channel telephone links and VF teleprinter links quite adequately.

Television, radar, data transmission, and other techniques developed during the 1940s and 1950s showed up the limitations of image-parameter theory. The higher precision and more exact characteristics required of filters from then on caused the image-parameter theory to give way to the modern network theory that uses synthesis techniques and digital computers.

One of the latest products of modern filter technology is the **surface acoustic wave filter**, which has an exciting performance, and can already be obtained at relatively low prices. Murata, for instance, produce a 10.7 MHz SAW that retails for less than £5 (available from Cirkit), and Plessey make units for the IF stages in TV receivers.

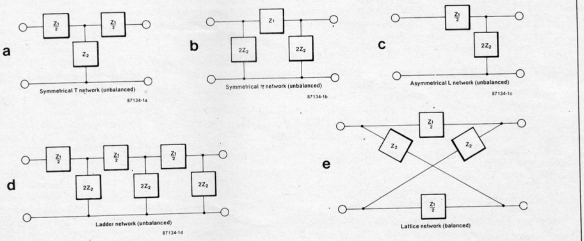
Surface acoustic wave filters have a superb rectangular frequency response with constant group delay: it is possible to make these filters and shape the two features separately—this is unique to SAWs. Their only disadvantages are a high insertion loss (20—30 dB), which results from the necessity of suppressing certain transmission reflective modes, and the necessity of temperature stabilization of the unit for certain applications: there is usually a price for everything!

General network concepts

Networks can be shaped like a **T**, a π, or an **L**, as shown in fig. 1. There is also a **ladder** network and a **lattice** network. The boxes in the diagram (and all others in this article) represent an impedance. This impedance may be a pure resistance, a reactance, or a combination of the two. It is customary to show series impedances in half, i.e. $Z_1/2$, and parallel (or shunt) impedances double, i.e. $2Z_1$. It will be seen that this eases the calculations.

Most networks and filters are unbalanced and one side is usually grounded. A notable exception is found where high levels of electromagnetic hum or RF interference prevail. This situation can arise in sound studios, particularly when these are co-sited with their parent transmitters. In these circumstances, the sound line distribution system is usually balanced. The balanced arrangement is made to cancel out induced currents in each leg of the lines.

1



a: Symmetrical T network (unbalanced)

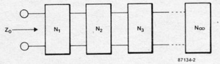
b: Symmetrical π network (unbalanced)

c: Asymmetrical L network (unbalanced)

d: Ladder network (unbalanced)

e: Lattice network (balanced)

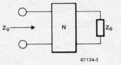
2



Characteristic impedance Z_0

The characteristic impedance, Z_0, is defined as the value of the input impedance of an infinite number of cascaded identical networks—see Fig. 2. From this definition, it follows that a network with a **terminating** impedance of Z_0 behaves as if it were infinitely long. Such a network is said to be matched—see Fig. 3.

3

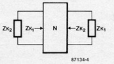


Since the network in fig. 3 is infinitely long, no signals can return from the far end. This reasoning also applies to a network matched in its own Z_0. It should be noted that even if a network is not matched in its own Z_0, and contains lossy impedances, it can be shown mathematically that it still tends to behave as though it were infinitely long.

Symmetrical or asymmetrical

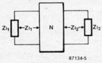
A network is **symmetrical** if its input and output terminals can be interchanged without causing any change in its electrical performance.
A network is **asymmetrical** if its input and output terminals can not be interchanged without causing any change in its electrical performance.

4



With asymmetrical networks, two conditions are of particular interest. In Fig. 4, an impedance Z_{K2} at one pair of terminals of network N produces a like impedance at the other pair of terminals. Similarly, an impedance Z_{K1} at the other pair of terminals produces a like impedance at the first pair of terminals. Impedances Z_{K1} and Z_{K2} are called **iterative** impedances. If the two iterative impedances are equal, their common value is the **characteristic** impedance of the network.

5

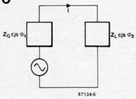


In Fig. 5, impedance Z_{I1} connected across one pair of terminals of network N causes an impedance Z_{I2} at the second pair of terminals, and an impedance Z_{I2} connected across the second pair of terminals causes an impedance Z_{I1} at the first pair. These two impedances are called **image** impedances.
In symmetrical networks, the iterative and image impedances are equal.

Maximum power transfer theorem

For a generator to supply power to a load at maximum efficiency, certain conditions must prevail. In Fig. 6, $Z_G\text{cjs}\Phi_1$ is the complex impedance of the generator and $Z_L\text{cjs}\Phi_2$ is the complex load impedance.

6



The total loop impedance is

$$Z_T = Z_G\text{cjs}\Phi_1 + Z_L\text{cjs}\Phi_2 =$$

$$= (Z_G\cos\Phi_1 + Z_L\cos\Phi_2) +$$

$$+ j(Z_G\sin\Phi_1 + Z_L\sin\Phi_2) \quad [1]$$

so that

$$\boldsymbol{Z}_T^2 = Z_G^2 + Z_L^2 +$$

$$+ 2Z_GZ_L\cos(\Phi_1 - \Phi_2)$$

Now,

$$\boldsymbol{I} = \boldsymbol{U}/\boldsymbol{Z}$$

and

$$P = \boldsymbol{I}^2 Z_L\cos\Phi_2$$

where $Z_L\cos\Phi_2$ is the resistive (real) part of Z_L.
From this

$$P = \frac{\boldsymbol{U}^2 Z_L\cos\Phi_2}{\{Z_G^2 + Z_L^2 + 2Z_GZ_L\cos(\Phi_1 - \Phi_2)\}} \quad [2]$$

Differentiating [2] with respect to Z_L with Φ_2 constant gives

$$dP/dZ_L = \frac{-\boldsymbol{U}^2\cos\Phi_2(1 - Z_G^2/Z_L^2)}{\{Z_G^2/Z_L + 2Z_G\cos(\Phi_1 - \Phi_2)\}^2} \quad [3]$$

Maximum power will be generated when $(1 - Z_G^2/Z_L^2) = 0$ (when, of course, [3] itself will be zero). Since Z_L is positive, $Z_L = Z_G$.

Differentiating [2] with respect to Φ_2 with Z_L constant gives

$$dP/d\Phi_2 = \frac{\boldsymbol{U}^2 Z_L((Z_G^2 + Z_L^2)\sin\Phi_2 + 2Z_GZ_L\sin\Phi_1)}{(Z_G^2 + Z_L^2 + 2Z_GZ_L\cos(\Phi_1 - \Phi_2))^2}$$

Maximum power transfer will take place when $dP/d\Phi_2 = 0$, which requires that

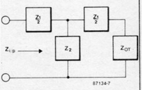
$$\sin\Phi_2 = -(2Z_GZ_L\sin\Phi_1)/$$
$$/(Z_G^2 + Z_L^2) = -\sin\Phi_1$$

It is, therefore, seen that maximum power transfer takes place when the generator impedance and load impedance are **conjugate**, that is, when their real parts are equal, and their imaginary parts (that is, phase angles) are equal in magnitude but opposite in sign. Note that if the generator impedance is variable, maximum power will be transferred when the real part of Z_G (that is, $Z_G\cos\Phi_1$) is zero.

Characteristic impedance

Symmetrical T network. In Fig. 7

7



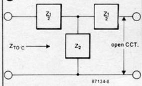
$$Z_{ip} = Z_1/2 + Z_2(Z_1/2 + Z_{0T})/$$
$$/(Z_2 + Z_1/2 + Z_{0T}) \quad [4]$$

from which after cross-multiplication and making $Z_{ip} = Z_{0T}$,

$$Z_{0T} = \sqrt{(Z_1Z_2 + Z_1^2/4)} \quad [5]$$

When the terminating output impedance is removed as in Fig. 8,

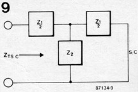
8



$$Z_{TOC} = Z_1/2 + Z_2 \quad [6]$$

When the output terminals are short-circuited as in Fig. 9,

9



$$Z_{TSC} = Z_1/2 + (Z_2Z_1/2)/(Z_2 + Z_1/2)$$

$$= (Z_1Z_2 + Z_1^2/4)/(Z_2 + Z_1/2) \quad [7]$$

Multiplying [6] and [7] gives

$$(Z_2 + Z_1/2)(Z_1Z_2 + Z_1^2/4)/$$

$$/(Z_2 + Z_1/2) =$$

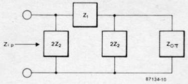
$$= Z_1Z_2 + Z_1^2/4 = Z_{0T}^2$$

and

$$Z_{0T} = \sqrt{(Z_{TOC}Z_{TSC})} \quad [8]$$

which provides a practical way of determining the characteristic impedance of the network.

10



Symmetrical π network. In Fig. 10,

$$Z_{ip}=\frac{2Z_2(Z_1+2Z_2Z_{0\pi}/(2Z_2+Z_{0\pi})}{2Z_2+Z_1+2Z_2Z_{0\pi}/(2Z_2+Z_{0\pi})}$$

from which, after cross-multiplication and making $Z_{ip}=Z_{0\pi}$,

$$Z_{0\pi}=Z_1Z_2/\sqrt{(Z_1Z_2+Z_1^2/4)} \qquad [9]$$

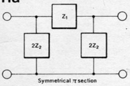
When the output terminals of the π network are open- and short-circuited, the results are similar to those for the T network, i.e.

$$Z_{0\pi}=\sqrt{(Z_{\pi oc}Z_{\pi sc})} \qquad [10]$$

By inspection, a further relationship between the T and π networks is

$$Z_{0\pi}Z_{0T}=Z_1Z_2 \qquad [11]$$

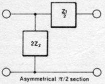
11a



Symmetrical π section

87134-11a

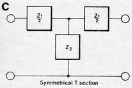
b



Asymmetrical π/2 section

87134-11b

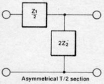
c



Symmetrical T section

87134-11c

d

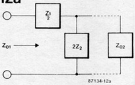


Asymmetrical T/2 section

87134-11d

L network or half section. This asymmetrical network is obtained by dividing either a T section or a π section in half as shown in fig. 11. This seemingly trivial operation yields some surprising and very useful results. Although the half sections look similar, they are not interchangeable as regards impedances. Characteristic impedance does not apply in the case of a half section: instead, it will be examined in terms of its image impedances.

12a



In Fig. 12a,

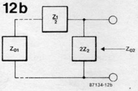
$$Z_{01}=Z_1/2+2Z_2Z_{02}/(2Z_2+Z_{02})$$

so that,

$$Z_{01}Z_{02}+2Z_2Z_{01}-(Z_1/2+2Z_2)Z_{02}=$$

$$=Z_1Z_2 \qquad [12]$$

12b



From Fig. 12b,

$$Z_{01}=2Z_2(Z_1/2+Z_{01})/$$

$$/(2Z_2+Z_1/2+Z_{01})$$

so that

$$Z_1Z_{02}-2Z_2Z_{01}+(Z_1/2+2Z_2)Z_{02}=$$

$$=Z_1Z_2 \qquad [13]$$

Expressions [12] and [13] can be added and subtracted from one another.
Subtracting gives

$$4Z_2Z_{01}-(Z_1+4Z_2)Z_{02}=0$$

from which

$$Z_{01}Z_{02}=(Z_1/4+Z_2)/Z_2 \qquad [14]$$

Adding gives

$$Z_{01}Z_{02}=Z_1Z_2 \qquad [15]$$

Combining [14] and]15] and removing Z_{01} gives

$$(Z_1/4+Z_2)/Z_2=Z_1Z_2/Z_{02}$$

so that

$$Z_{02}^2=Z_1Z_2^2/(Z_1/4+Z_2)\times Z_1/Z_1=$$

$$=Z_1^2Z_2^2/(Z_1Z_2+Z_1^2/4)$$

from which

$$Z_{02}=Z_1Z_2/\sqrt{(Z_1Z_2+Z_1^2/4)}=Z_{0\pi}$$

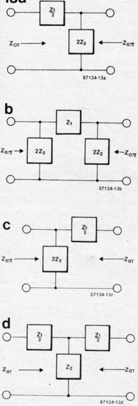
(from [9])

In similar fashion, it can be shown that

$$Z_{01}=Z_{0T}$$

The results obtained—shown in Fig.13—make clear he value of the half section for matching purposes.

13a



Note that expressions [8] and [10] are true for the two image impedances, but not for the iterative impedances, which must be determined from first principles.

Propagation constant

In a finitely long cascade of similar networks, the parallel elements provide current paths back to the sending end. These return currents do not flow through the load terminating the cascade. Likewise, the series elements cause voltage drops along the cascade. The net result of these factors is that power is lost in the networks. Of course, if the cascade is infinitely long, all voltages and currents would have decayed to zero. This decay of, for instance, a voltage, U, is expressed by the exponential function

$$U=E\exp(-\gamma l)$$

where E is the starting voltage, γ is the propagation constant, and l is the length down the cascade. Note that when $l=0$, $U=E$.
This function is true for the ratios of currents and voltages down the cascade, provided this is a regular array of series and parallel elements.
Therefore,

$$i_1/i_2=i_2/i_3=i_{\infty-1}/i_\infty=\exp(\gamma) \qquad [16]$$

The propagation constant $\gamma=\alpha+j\beta$, also called propagation coefficient or image transfer constant, is of special significance in network theory. It is a complex number, of which the real part, α, is called the alteration coefficient or image attentuation coefficient, and the imaginary part, β, is called the phase shift coefficient or the image phase constant.
$I_1/I_2\exp(\alpha)$ gives the amplitude variation, whence

$$\alpha=\log_e(I_1/I_2) \quad \text{[nepers]} \qquad [17]$$

Similarly,

$I_1/I_2\exp(\beta)$ gives the phase between the currents, whence

$$\beta=\log_e(I_1/I_2) \quad \text{[radians]} \qquad [18]$$

One neper (Np) equals 8.686 decibels (dB), Summing the voltages around the loop A-B-C-D in Fig. 14 gives

$$I\exp(2\gamma)Z_1+[I\exp(2\gamma)—I\exp(\gamma]Z_2—[I\exp(3\gamma)——I\exp(2\gamma)]Z_2=0$$

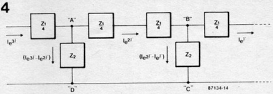
which, when divided by $I\exp(2\gamma)$ gives

$$[\exp(\gamma)+\exp(-\gamma)]/2==\cosh\gamma=1+Z_1/2Z_2 \qquad [19]$$

Note that when $\gamma=0$, $\cosh\gamma=1$; the hyperbolic cosine is symmetrical about the *Y* axis.

Part 2 of this article will appear in our September issue.

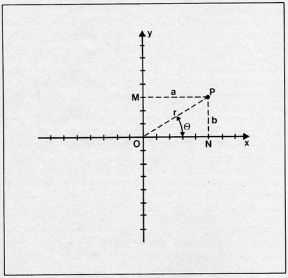
14



Complex numbers

For some readers, it may be useful to reconsider briefly the properties of complex numbers, sometimes called complex quantities.
A good way to understand complex numbers and algebraic operations with them is to consider that they represent a point in a plane. In the diagram, the complex number $a+jb=5+3j$ represents a point *P*, which has the abscissa $a=5$ and the ordinate $b=3$. The distance of *P* from the coordinate centre is the hypothenuse of the right angle *ONP*, which is

$$OP=\sqrt{(a^2+b^2)}=\sqrt{(25+9)}=5.83$$



The angle θ that OP makes with the *x*-axis is given by

$$\tan\theta=NP/ON=b/a=3/5=0.6$$

Instead of representing a complex quantity by its rectangular coordinates *a* and *b* in the form $a+jb$, it can also be represented by its polar coordinates, i.e., the distance, *r*, of P from the coordinate centre, 0, where

$$r=\sqrt{(a+b)}$$

and the phase angle θ between the radius *r* and the *x*-axis, where

$$\theta=\arctan(b/a)$$

which is read as "the angle whose tangent is b/a".
With reference to the diagram

$$a=r\cos\theta \quad \text{and} \quad b=r\sin\theta$$

so that the complex quantity, $P=a+jb$, can also be written as

$$P=r(\cos\theta+j\sin\theta)$$

which is often abbreviated to $r\text{cis}\theta$ or $r\text{cjs}\theta$, and sometimes written as $r\underline{/\theta}$, which is read as "*r* at the angle *θ*".
Note that mathematicians use "*i*" to denote the concept of $\sqrt{-1}$, while electrical engineers use the "*j*" to avoid confusion with the use of "*i*" to represent an electric current. The distance *r* in the diagram is called a **vector** by methematicians but a **phasor** by electrical engineers.
Two complex numbers are equal only if their real and imaginary parts are equal. If, therefore,

$$a+jb=c+jd$$

then $a=c$ and $b=d$

Consequently,

$$(a+jb)+(c+jd)=(a+c)+j(b+d)$$

The same rule applies to the subtraction of two complex numbers.
The multiplication of complex numbers is carried out in the conventional manner, but it should be borne in mind that $j^2=-1$ and, therefore, all higher powers of *j* can be eliminated:

$$j^1=j \quad j^2=-1 \quad j^3=-j \quad j^4=+1 \quad j^5=j \quad \text{and so on.}$$

$$(a+jb)(c+jd)=ac+jad+jbc+j^2bd=$$

$$=(ac-bd)+j(ad+bc)$$

The division of complex numbers is carried out by multiplying both numerator and denominator of a fraction by the conjugate of the denominator. For instance, in the fraction $(a+jb)/(c+jd)$, multiply both parts by $(c-jd)$. Thus,

$$(a+jb)(c-jd)/(c+jd)(c-jd)=$$

$$=[(ac+bd)+j(bc-ad)]/(c^2+d^2)=$$

$$=(ac+bd)/(c^2+d^2)+j[(bc-ad)/(c^2+d^2)]$$

WHERE STUDENTS MAKE THEIR OWN CHIPS

by Brian Lawrenson, Department of Physics and Electronic Engineering, University of Dundee

Electronics engineering graduates entering industry often meet difficulties in translating theory into practice. The advanced technology of making chips is probably one of the biggest hurdles they have to face. A Scottish university is tackling the problem by getting its students to turn out chips in the laboratory.

When the Irish dramatist George Bernard Shaw wrote his condemnation of the teaching profession, "He who can, does. He who cannot, teaches", he came close to identifying one of the main difficulties in educating engineering students. It lies in ensuring that the teaching of theoretical principles is firmly identified with the real world of engineering design and manufacture.

Most degree courses in electronics engineering include lectures on the principles of semiconductor devices, explaining how such components as transistors and diodes operate. At the University of Dundee we have taken this study one stage further: undergraduates are regularly designing and making silicon chips as part of their normal project and laboratory work.

Our involvement with this branch of engineering began several years ago because the University is close to makers of semiconductors in central Scotland, in an area known as 'Silicon Glen'. When we took part in the usual type of organised student visit to these companies it was clear that many of the undergraduates were very attracted to their high technology and ultra-clean working conditions, so we invited a number of semiconductor engineers to make regular visits to the University to contribute to some of the lecture courses.

From these early beginnings we have been able to set up a microelectronics laboratory which has all the facilities needed to design, manufacture and test silicon integrated circuits. The very high capital costs usually associated with this type of work have been largely avoided by obtaining used professional equipment from industry, either by donation or by paying a modest amount. It has often meant that we have had to wait patiently for suitable items to become available and a lot of time has been spent on repairs and modifications. It has taken some 11 years for the laboratory to reach its present level of operation.

In spite of the fact that the term silicon chip has been much paraded by journalists and broadcasters, relatively few people know how the devices operate or how it is possible to make something which is so small and yet so complex.

Most chips are made from silicon (Si), an abundant chemical element which has two fortuitous properties. First, it is easy to oxidise its surface in a furnace to produce a stable coating of silicon dioxide glass (silica), which is an excellent electrical insulator. Second, it is easy to change the value of its electrical conductivity by adding relatively small amounts of either phosphorus or boron. The electric currents which flow in silicon are due to the movement of negatively-charged electrons (*n*-type Si) or, on the other hand, due to what appear to be positively-charged particles known as positive holes (*p*-type Si). The latter behaviour is somewhat surprising; it arises from the way in which electrons interact with atoms of silicon, especially in the presence of certain other types of atom such as boron.

The simplest active component of an integrated circuit is the MOSFET (Metal Oxide Semiconductor Field Effect Transistor). Its structure is shown in the first diagram, where phosphorus and boron have been used selectively to form regions of differing conductivity and silica of varying thickness has been used to provide electrical insulation where required. This transistor will switch on if an electric field is created below the gate electrode by applying a positive voltage to it. Electrons are attracted into the central region of the device and a current can then be made to flow through it from the source to the drain contacts: the MOSFET is then acting as a switch which has no moving parts and which is actuated by electrical means.

This switching property means that groups of transistors may be used to transmit and process information presented in the form of a binary code. A complete digital integrated circuit may have more than 100 000 MOSFETs formed just below the surface of the silicon and interconnected by a top layer of fine aluminium tracks. A most important characteristic of such a circuit is that it is fairly insensitive to differences in the per-

1

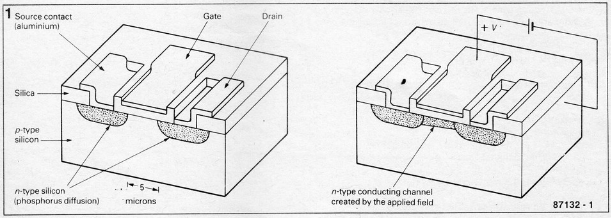


Fig. 1. Structure of the basic MOSFET (left). Application of a positive voltage *V* to its gate (right) switches the transistor into the 'on stage.

formance of individual transistors; as long as each switches on and off, all is well.

In making a chip, the details of every feature in one layer of its structure are first recorded on a high definition photographic plate. For instance, all of the sources and drains in the entire circuit would appear in the photograph as transparent rectangles on a black background each measuring some five micrometres square. Because the whole chip will be only about five millimetres square or even smaller, there is room on the plate for the detail contained in at least 200 identical chips, arranged on the photograph like a sheet of stamps. This detail is then transferred to the surface of the silicon by a process called photolithography. It means coating the oxidised surface of a thin disc of silicon (called a silicon wafer) with a layer of a substance known as photoresist, which is sensitive to ultraviolet light. Using the photographic plate and UV light produces an image of the circuit features in the photoresist which, when treated with acid, reveals the source and drain regions as tiny rectangular holes in the silica and exposes the surface of the silicon.

Manufacturing processes that follow include the diffusion of boron or phosphorus through the holes in the silica into the surface of the wafer, in furnaces at temperatures of about 1100°C. Finally, the whole wafer is coated with a thin layer of aluminium in a vacuum chamber, and photolithography etches it into the pattern of metal tracks which connect the transistors. The details of each layer derive from its particular photomask.

2

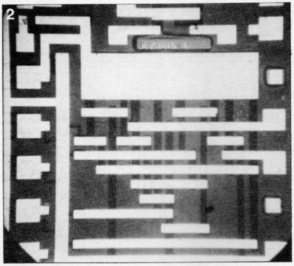


Fig. 2. Photomicrograph of a chip 1.8 mm square made by a student.

Our microelectronics laboratory is equipped for all these processes, in a suite of cleanrooms with a filtered air supply to exclude dust. It has it own photographic unit with cameras for making the photomasks. One cleanroom is reserved for photolithography and another for the 10 electrically heated furnace tubes with their associated gas supplies. The largest area has probing equipment for making electrical test measurements on the finished wafers. There is also equipment for sawing the wafers into separate chips and for mounting them in their familiar plastic boxes with metal legs.

Project Time

A student at Dundee who opts for this work will spend some 300 hours of project time designing and making a chip to his or her own specifications. The circuit has to be fairly simple, of course, with fewer than 150 transistors. We find that MOSFETs with *p*-type channels are simplest to make and we are usually content to turn out devices with a separation of 10 μm between source and drain. The layout details for each chip are designed with the aid of a mainframe computer and are stored on magnetic tapes. Initial artwork is produced from the tapes using equipment for reproducing weather satellite photographs (we have not been fortunate enough to obtain the appropriate pattern generator for this stage). The main fabrication processes are then undertaken. To make working conditions as realistic as possible, everyone wears a full set of cleanroom clothing resembling a surgical hood and gown. Students are also asked to assess the cost of bringing each design to fruition.

This activity provides a wealth of practical experience and puts the importance of the lecture courses into perspective. Students are encouraged to consult key research papers as well as standard textbooks, to help them identify causes of unexpected results or failures that arise from time to time in the work. The aspiring integrated circuit engineer soon begins to appreciate the importance of mastering the required blend of electronics engineering, solid state physics, chemistry, crystallography and metallurgy, backed-up by computer-aided design techniques.

Almost 40 Honours students have now been introduced to integrated circuit engineering through the work of the microelectronics laboratory. Postgraduate research and industrial contract work are supported, too. Dundee graduates in this field are now working for major manufacturing companies in the UK and overseas, including GEC, Plessey, Ferranti, Hughes Microelectronics, National Semiconductor, Motorola, British Telecom, INMOS, Mullard and Siemens. The chips our former students have been working on include the Transputer and many other devices. Through this we gain useful feedback about the content of lecture courses and the areas that are interesting for research.

Employers have been enthusiastic about this practical approach to microelectronics. When our graduates go to their first job interviews carrying silicon chips that they have made themselves, their starting salaries have been good.

EW PRODUCTS • NEW PRODUCTS • NEW

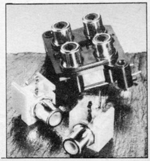
Extensive range of phone sockets

As part of its rapidly expanding service supplying high-quality Japanese components to the UK, Watts International announces an extensive range of phone sockets.

The Emuden manufactured range features a remarkable number of socket types, including single, double, and multiple connectors. The multiple units are available as complete items, or they can be ganged from a variety of single or double interlocking connectors. Complete multiple assemblies are available with three, four, five, six, and ten connectors. The outer earth cap may be standard or chamfered.

Watts International
Components Limited
Suite 6
Wyvern House
46-48 High Street
BOGNOR REGIS PO21 1SP
Telephone: (0243) 868322

(3630-28F)



ATN FILMNET DECODER

by J & R v Terborgh

Believe it or not, but a few days after our May issue was sent to the printers, the engineers at ATN Filmnet altered the station's scrambling system. The next thing that happened was Sky Channel abandoning encoding altogether for roughly a fortnight.
An article written for naught and circuits doomed to end up in the junkbox? Here is the updata!

The speed at which dramatic changes take place in the satellite TV world is very hard to keep up with. After the publication of (1), we saw Europa TV dissappear and their 3WH transponder temporarily assigned to 3-SAT, Music Box change into Super Channel, and ATN Filmnet adopt the Matsushita scrambling system, all on ECS-1. The launch of the DBS services for Federal Germany and France was postponed for the umpteenth time, the flat dish was developed to aid in individual reception, Europe witnessed an invasion of relatively inexpensive LNBs of Far Eastern origin, and many of our readers embarked on setting up their own reception system.

Roundabout March 26 of this year, pay-TV channel ATN Filmnet selected scrambling mode 2 as a follow-up of mode 1, which was analysed in (2), and had been in operation since September 1, 1986. Until that memorable day, it was not generally known that their Matsushita scrambling system can be programmed to provide *several* scrambling modes. It has now evolved that subscribers' decoders incorporate a microprocessor-based system that selects and combines a number of essentially simple decoder blocks. This selection goes by wholly unnoticed to the registered subscriber, and is effected with the aid of a special code packet transmitted via the digital subscriber's data channel at 7.02 MHz in the baseband —see Fig. 1. It must reiterated here that the scrambling system itself is **not** digital, and it is readily seen that the power of this multi-mode scrambling system resides in the possibly large number of available *combinations* of methods, rather than in the *complexity* of each individual method. Therefore, now that mode 2 is operative, the use of the mode 1 decoder proposed in (2) is the same as using no decoder at all, since in both cases the picture is completely unintelligible. And yet, the essence of the newly adopted encoding method remains very simple, and is but an extension of mode 1, so that the design idea brought forward in (2) remains the basis for any further designs.

New circuits for new modes: 2 all

The circuit diagram in Fig. 2 shows how the functional blocks of Fig. 3 in (2) have been worked out into a practical decoder. The 7.6 MHz FM receiver for obtaining the composite blanking signal is purposely shown as a separate unit here to make clear that it is always required for decoding ATN Filmnet, whatever scrambling mode is, or will be, adopted (it may well be that mode 3 or even 4 is operative when this article is being published...). The PLL and pulse timing sections are largely identical to those used in the Sky Channel decoder (2), so that a detailed description of these is not required here.

As already stated, mode 2 is an extended version of mode 1. In addition to shifting the DC component of the blanking, and inversion of the entire signal, the polarity of the video signal is now toggled for each raster in the interlaced picture. This is very simple to put right by dividing the 50 Hz blanking component by two in bistable FF_1, and alternately selecting the DC-corrected VIDEO or $\overline{\text{VIDEO}}$ signal from the NE592 differential amplifier on the vision/sound/PSU board in the Elektor Electronics Indoor Unit for Satellite TV Reception (3). Provision has been made to ensure that a viewable signal is always available at the AC coupled and CVBS-1 output. This is effected by rectifying the raster pulses in D_3-C_{29}-R_{25} and using the logic level so obtained to select between the decoder output and the receiver's CVBS-1 signal. LED D_4 lights when the signal from ATN is encoded. When it is not encoded, which is sometimes done on purpose between films and during announcements of forthcoming programmes, the carrier at 7.6 MHz is simply left unmodulated.

Since it was intended to keep the decoder as simple as possible, no provision has been made for automatically selecting the correct frame polarity of the video signal. This means that the SYNC button may have to be pressed a few times to obtain a properly decoded picture. The decoder remains synchronized when ATN switches between encoded and non-encoded transmissions, but loses synchronization if the signal strength at the receiver input is too low, since spikes then upset the operation of the filters and the PLL Type 4046.

1

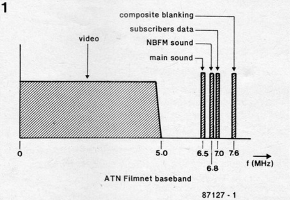


Fig. 1. Frequency assignment in the baseband transmitted by ATN Filmnet.

In practice

It must be pointed out here that the decoder experiments discussed require a certain amount of feeling for dealing with RF and video signals. Also, the material presented here is essentially but a design idea, and the construction and align-

2

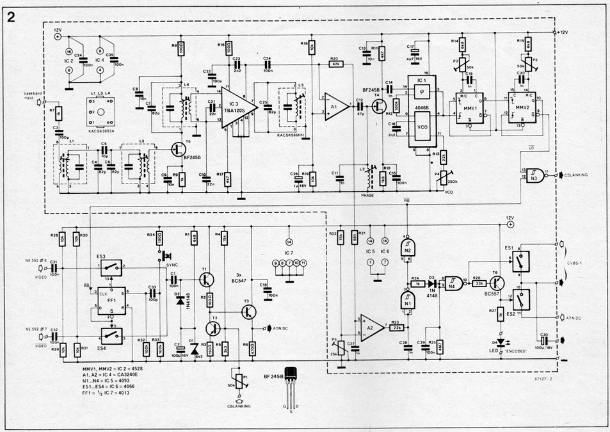


Fig. 2. Suggested design of an experimental mode 2 decoder for ATN Filmnet, the Dutch pay-TV channel on ECS-1.

ment of the circuits are given as a guide for advanced constructors and for experimental purposes only.

Although ready-made inductors are shown in the L_1 and L_3-L_5 positions, it is very well possible to make your own from available materials: this is likely to ensure a rather higher Q factor, and is certainly worth trying when a grid dip meter is available. Use an RF signal generator to peak the top-coupled bandfilter and L_4 at 7.6 MHz, and carefully tune L_5 to that frequency by monitoring the output of the FM decoder with the aid of a scope. Be sure to steer clear of the other signals in the baseband. The operation and adjustment of the line blanking processor and pulse filters need no further detailing here, since this has been dealt with in ⑵. The CBLANKING signal from the FM receiver is, of course, eminently suitable for triggering an oscilloscope while analysing further scrambling methods from ATN's bag of tricks.

Conclusion

Although the station controllers at ATN Filmnet may change to another of several more encoding methods, this subject is concluded here to concentrate on other matters to do with satellite TV reception. As already stated, there is no way of knowing whether the "mode 2" circuit described here will be of use by the time this article is printed, but enough technical information should now be available to readily spot any changes to the scrambling system, and enable modification of the relevant circuit sections.

Bu:RGK

Literature references:

Elektor India, October 1986.
⑵ *Decoding satellite TV signals. Elektor India*, June 1987.
⑶ *Indoor Unit for Satellite TV Reception — 2. Elektor India*, December 1986.

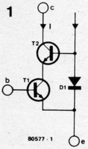
---

hybrid cascode

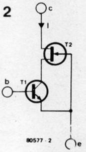
It is general knowledge that cascoding two or more transistors creates a new transistor with better characteristics than the individual ones (see figure 1). These include a very slight retroaction from point C ('collector') to point B ('base') and a higher collector impedance, thus a much better approach to current source operation at point C.

In the all transistor version of figure 1, the base of T2 will have to be fed a certain voltage with respect to the emitter of T1 — 0.6 volts (D1 in figure 1) at least.

1



2



If T2 is replaced by an N channel FET, the DC bias of the cascode will be a lot easier to preset — see figure 2. As far as slope is concerned (i.e. the ratio between collector current and base voltage) both versions are equally good.

infra-red light gate

This article describes an infra-red light source and detector, which can be used in a wide variety of applications ranging from intruder alarms to automatic garage door openers. When the light beam from the infra-red source is interrupted, the receiver circuit detects this and energises a relay.

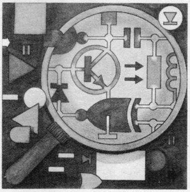
The use of an infra-red light source is an obvious choice for this type of application. In the first place, for intruder alarm applications the light beam must be invisible, which limits the choice to infra-red or ultra-violet light. Ultra-violet light can cause visible fluorescence of certain materials, which makes it less suitable than infra-red. In the second place, relatively powerful solid-state infra-red sources, and infra-red sensors, are available at modest cost, whereas there are no solid-state UV sources commercially available.

The circuit described here uses the Siemens LD 241 infra-red emitter and BPW 34 IR photodiode.

Although these devices are not exorbitantly priced, neither are they inexpensive, so in order to minimise the number of IR emitters necessary to achieve a given range the transmission system should be as efficient as possible. Since the light level received at several metres distance from the transmitter will be very low, the receiver must have a high gain. This immediately excludes the simpler types of photoelectric switch that use a continuous light beam and a DC-coupled receiver, since a high-gain DC coupled receiver amplifier would be prone to offsets, temperature drift and other effects that could lead to poor sensitivity on the one hand, or false triggering on the other.

The choice therefore falls on an AC modulated light beam and AC-coupled receiver, since a high AC gain can be achieved without offset problems. Such a system can be either narrowband or wideband. The advantages of a narrowband system are a higher signal-to-noise ratio and less susceptibility to extraneous interference, either in the form of ambient light or transients on the supply lines. The disadvantage of a narrowband system is that the transmitter and receiver frequencies have to be accurately aligned.

In a wideband system, the light source is simply pulsed on and off, and the amplification stages of the receiver have a fairly large bandwidth. The advantages of this system are simplicity and ease of alignment, but the disadvantages are poor signal-to-noise ratio and susceptibility to interference. However, advantage may be taken of the fact that the infra-red emitting diode will withstand a peak current that is much larger than the average current (1 A peak as against 100 mA continuous). Small duty-cycle, high-power pulses may thus be transmitted, which will give an improved signal-to-noise ratio over a larger duty-cycle transmission of the same average power.



The effects of external sources of interference may be reduced by careful attention to constructional layout, mounting the unit in a screened box, and suppression of the supply lines. With these precautions a wideband system can give quite acceptable performance and was thus chosen because of its other advantages.

Transmitter circuit

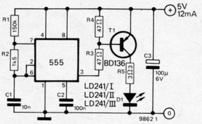
The simple transmitter circuit is shown in figure 1. It consists of a 555 timer connected as an astable multivibrator, driving an output transistor which switches the IR emitter on and off. The duration of the transmitted light pulses is about 10 μs and the repetition rate is just less than 1 kHz. The average current drawn by the circuit is about 12 mA and the peak current through the IR diode is around 700 mA.

The LD241 is available in three versions, LD 241/I, LD 241/II and LD 241/III, which have different radiant intensities. For the same forward current, the light output of the LD 241/II is typically 1½ times, and the light output of the LD 241/III typically 2½ times, that of the LD 241/I.

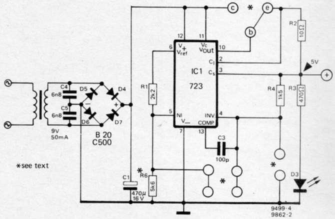
The power supply for the transmitter is not critical provided the output voltage is no greater than 6 V, as this could result in the maximum current rating of the LD 241 being exceeded. A suitable circuit is given in figure 2 and can be built up on the board for the 'Local Radio' power supply (Elektor 22, February 1977).

Note that the component values for this circuit differ from those of the original circuit (see parts list) and that the following components are omitted: R5, C2 (replaced by R6), D1, D2, T1 (base and emitter connections linked on the p.c.b.).

1



2



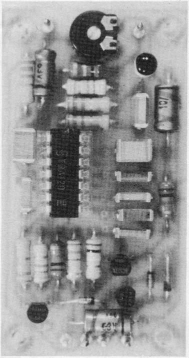
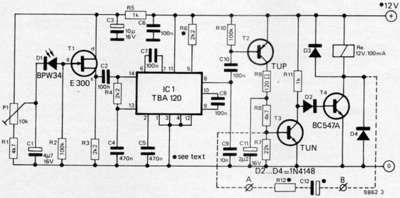


Figure 1. Circuit of the infra-red transmitter.

Figure 2. The 'Local Radio' power supply may be modified to provide a 5 V supply for the IR transmitter. Since the average current is only 12 mA, the external transistor T1 may be omitted.

Figure 3. Circuit of the infra-red receiver.

3



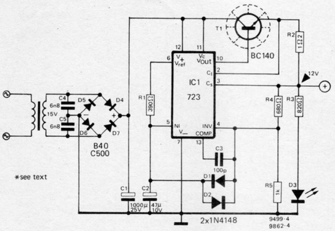
Receiver circuit

The receiver circuit is shown in figure 3. A BPW34 infra-red photodiode is operated in the reverse-bias mode. The leakage current of this diode varies with the light received from the transmitter, which causes a varying voltage to appear across resistor R2, the gate resistor of the FET source-follower T1. The signal appearing at the source of T1 is fed to IC1, which is used as an amplifier and limiter. P1 varies the sensitivity by altering the reverse bias voltage of the diode.

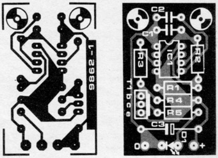
When light pulses are being received from the transmitter, a negative-going pulse train with an amplitude in excess of 1 V peak-to-peak appears at the output of IC1 (pin 8). This turns T2 on and off continually, charging up C11. T3 is thus always turned on, T4 is turned off and relay Re is not energised.

When then light beam between the transmitter and receiver is interrupted, the amplitude of the pulse train from the output of IC1 will fall. T2 will be cut off, C11 will discharge, T3 will turn off and T4 will turn on, pulling in the relay. Once the light beam is restored the relay will, of course, drop out again, but can be made to hold in for several seconds after the light beam has been restored by adding the components shown dotted. R12 should be

4



5



Parts list for figure 5

Resistors:
R1 = 150 k
R2 = 1k5
R3,R4 = 47 Ω
R5 = 3Ω3

Capacitors:
C1 = 10 n
C2 = 100 n
C3 = 100 µ/6 V tantalum

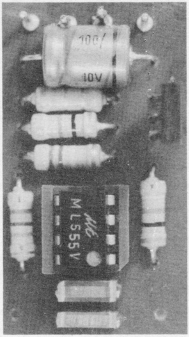
Semiconductors:
IC1 = 555 timer
T1 = BD 136
D1 = LD 241/I,/II or/III

Figure 4. The power supply for the receiver is simply a 12 V version of the 'Local Radio' power supply.

Figure 5. Printed circuit and component layout for the transmitter. (EPS 9862-1).

Figure 6. Printed circuit board and component layout for the receiver (EPS 9862-2).

Figure 7. Printed circuit board and component layout for the power supplies (EPS 9499-2).



4k7 and C12 can be from 10 µ to 100 µ, depending on the desired hold-in time. Alternatively a latching arrangement may be used that will hold the relay in until a reset button is pressed.

Power supply

A power supply for the receiver circuit is shown in figure 4. This is virtually identical to the power supply for the 'Local Radio' and may be built on the same board.

Construction

Printed circuit board and component layouts for the transmitter and receiver are given in figures 5 and 6. Construction of the transmitter should present no problems.

When constructing the receiver, great care must be taken with the layout due to the high sensitivity and large bandwidth. The leads to the BPW 34 photodiode must be as short as possible, as otherwise they may pick up interference. The relay should preferably *not* be housed in the same box as the receiver, as the magnetic field set up when it is energised may completely saturate the sensitive receiver input stage, causing the relay to drop out immediately. The receiver will then begin to function again, the relay will pull in and the whole process will repeat. If the relay must be mounted in the same box as the receiver, then it should be mounted as far as possible from the receiver input stage, and must be magnetically and electrically screened.

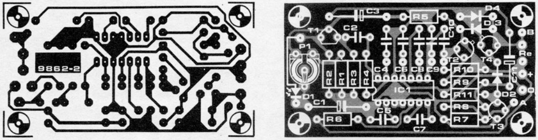
The receiver itself should be mounted in a metal box for screening, the only holes in the box being for relay and supply leads, an adjustment hole for access to P1 and a hole for the photodiode. Since the photodiode is sensitive to visible as well as infra-red light, it must be fitted with an infra-red filter (obtainable from photographic suppliers) if the unit is to be used in daylight. Even with the infra-red filter, direct sunlight should not be allowed to fall on the photodiode, since its large infrared content could affect the diode biasing and hence the receiver sensitivity. Some kind of hood or tube to screen the diode may be necessary in such circumstances.

Adjustment

The transmitter diode and receiver diode should be aligned with one another, although the radiation pattern of the one and the acceptance angle of the other are so wide that a slight misalignment will have little effect (but remember that a screening hood or tube on the photodiode will reduce the acceptance angle). The circuit is then checked for reliable operation at close range by breaking the infra-red light beam, after which the transmitter and receiver are moved progressively further and further apart, whilst P1 is adjusted to obtain the maximum range. If the photodiode is well screened from ambient light, this adjustment will have little effect and the wiper of P1 can simply be turned fully clockwise.

As it stands, the circuit will function at distances of up to 6 meters between the transmitter and receiver. If lenses are used to concentrate the transmitted light into a much narrower beam and to focus the received light on the photodiode then much greater ranges can be achieved. However, the physical

6



Parts list for figure 6

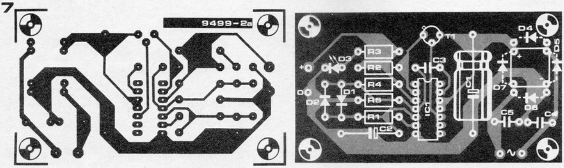
Resistors:
R1,R8 = 4k7
R2,R10 = 100 k
R3,R4,R6 = 2k2
R5,R11 = 1 k
R7 = 22 k
R9 = 120 Ω
R12 = see text

Capacitors:
C1 = 4μ7/16 V
C2,C6,C7,C8,C10 = 100 n
C3 = 10 μ/16 V
C4,C5 = 470 n
C9 = 10 n
C11 = 2μ2/16 V
C12 = see text

Semiconductors:
IC1 = TBA 120
T1 = E 300
T2 = TUP
T3 = TUN
T4 = BC 547A,BC107A
D1 = BPW 34 IR photodiode
D2,D3,D4 = 1N4148

Miscellaneous:
P1 = 10 k preset
Re = relay with 12 V/100 mA(max) coil

7



Parts list for figure 7, for circuit shown in figure 2:

Resistors:
R1 = 2k2
R2 = 10 Ω
R3 = 470 Ω
R4 = 1k5
R5 = omitted
R6 = 5k6 (replaces C2 on p.c.b.)

Capacitors:
C1 = 470 μ/16 V (tantalum)
C2 = replaced by R6
C3 = 100 p
C4,C5 = 6n8

Semiconductors:
T1 = omitted
IC1 = 723
D1,D2 = omitted
D3 = LED
D4 . . . D7 = 4 x 1N4002, or 20 V 500 mA bridge rectifier

Miscellaneous:
Transformer = 9 V 50 mA sec.

Parts list for figure 7, for circuit shown in figure 4:

Resistors:
R1 = 390 Ω
R2 = 1Ω
R3 = 820 Ω
R4 = 680 Ω
R5 = 1 k

Capacitors:
C1 = 1000 μ/25 V
C2 = 47 μ/10 V
C3 = 100 p
C4,C5 = 6n8

Semiconductors:
T1 = BC 140
IC1 = 723
D1,D2 = 1N4148
D3 = LED
D4 . . . D7 = 4 x 1N4002 or 40 V/500 mA bridge rectifier

Miscellaneous:
Transformer = 15 V/250 mA sec.

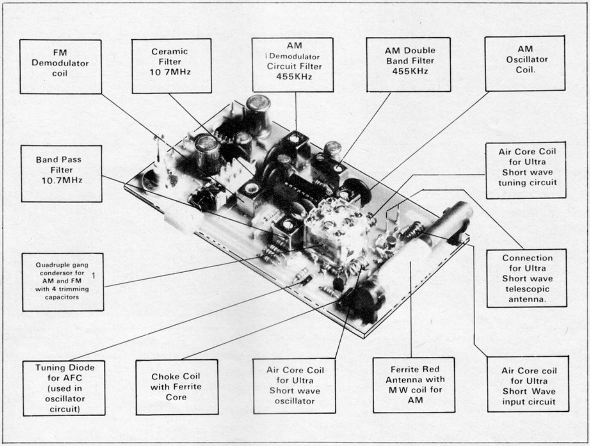
alignment of the transmitter and receiver will then be much more critical.

Notes on the TBA 120

The TBA 120 is produced by several manufacturers, and several different versions are available. All of these should function satisfactorily in the receiver circuit. However, in some cases it may be necessary to omit R6 (see figure 3) or connect it to ground instead of $+U_b$, to obtain the best signal-to-noise ratio. To check this the output of the IC should be monitored, either on an oscilloscope, or by connecting a pair of high impedance ($>$ 500 Ω) headphones between pin 8 of the IC and $+U_b$. When receiving a signal from the transmitter a 1 kHz signal should be heard (or seen). The effect of omitting R6, or connecting it to ground, can thus be investigated. The optimum result is indicated by the loudest (highest amplitude) signal. Care should be taken when altering R6 not to disturb the relative positions of the receiver and transmitter, as this could give false results. ◾

selex 26

HIGH FREQUENCY COMPONENTS



These types of components are also generally known as RF components. These are mostly passive elements used in a radio receiver. (or even a transmitter.) Due to continuous technological developments, new types of components keep on appearing on the market and slowly the old types find their way to the hobbyists junk boxes.

For a quick reference, we are giving here a short description of various such components.

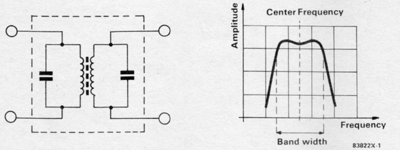
Rotary Condensors

Rotary condensors are mainly used for tuning applications. A gang condensor such as the one shown in photograph 1 is used in the tuning stage of a radio receiver. It consists of two stacks of metalic fins, one called the stator and one called the rotor. The rotor stack is mounted on the spindle and by rotating this, one can change the overlapping area between the stator and rotor fins.

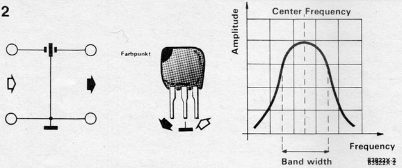
Minimum requirement of any radio set is two rotary condensors ganged together — one for the tuning circuit and the other for the oscillator circuit. There can be more than two such rotary condensors combined together, in case of AM/FM radios. Fins of the AM condensor are larger than the one for FM. Photograph 1 shows a double—AM/triple FM gang condensor. In transistor radios we find mostly miniature rotary condensors in a plastic casing. The dielectric material used here is not air, as in the larger ones, but a plastic film. Even the plates of the stator and rotor are thin metal foils. This helps in increasing the packing density and reducing the size.

Trimming capacitors are also used on these gang condensors for accurate tuning of the oscillator frequency. These are small rotary disc capacitors with plastic film dielectric. In case of ceramic disc trimmers, a ceramic disc

1



2



3

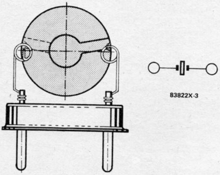


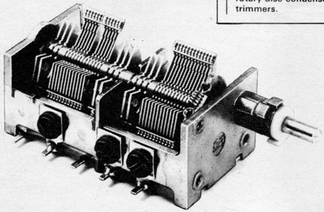
Figure 1:
Internal circuit and frequency response of a band pass filter.

Figure 2:
Circuit symbol, pin configuration and frequency response of a ceramic filter.

Figure 3:
Symbol and internal construction of a quartz crystal.

Photograph 1 :
Gang condensor with double AM and triple FM variable rotary disc condensors, and trimmers.

1



coated with silver forms the rotor part.

Trimmers mostly have very low capacities ranging from 5 to 15 pF for FM and upto about 100 pF for AM. The gange condensors have values from 200 pF to 600 pF.

Coils and Filters

These are inductors, either with air core or with ferrite core. The number of turns of copper wire, coil diameter and the material of the core decide the inductance value. The more the number of turns, higher is the inductance. A ferrite core gives more inductance value compared to an air core for the same coil winding. If the ferrite core is not fixed, moving it in or out of the coil winding can give a variable inductance value.

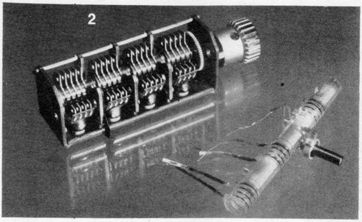
A variable inductor can also be used to tune the radio receiver. This is called Variometer tuning. The lower the frequency to be tuned, the higher must be the inductance value. Thus, an air core coil is useful for Ultra Short Wave tuning. Medium Wave tuning requires ferrite core coils.

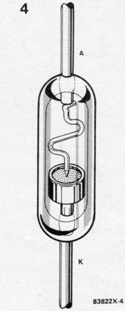
Coils are also used in filter circuits, which allow only a particular range of frequencies to pass through to the next stage. Internal circuit and frequency response of a bandpass filter is shown in figure 1. It consists of two coils coupled with a ferrite core and connected with two capacitors in parallel. Older types of these filters, and I.F. Transformers used to be very large in size, but in the modern transistor radios, their sizes have shrunk to just about one cubic centimeter.

Even the modern fixed value inductors have sizes and appearance similar to small resistors.

Ceramic Filters

Similar to coil filters, we also have ceramic filters to work as band pass filters. One such filter is shown in





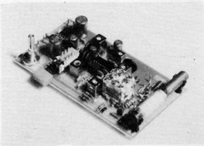


Figure 4:
Germanium point contact diode.

Figure 5:
Circuit symbol and capacitance curve of a tuning diode

Photograph 2 :
Quadruple gang condensor and variable inductor.

Photograph 3 :
Different trimming condensors: ceramic trimmers, plastic trimmers and air trimmers.

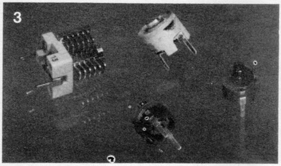
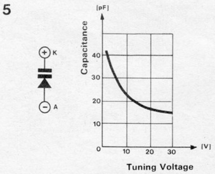


figure 2, with its circuit symbol, pin configuration and the frequency response. These look similar to plastic film capacitors, but may have 3 to 5 terminals instead of just two. They contain disc ceramic resonators in place of the resonant circuits made of coils and capacitors. The resonators are excited into mechanical vibrations only at the resonant frequency and can couple the incoming signal to the next stage. At all other frequencies, they do not get excited into vibrations and act as open circuits.

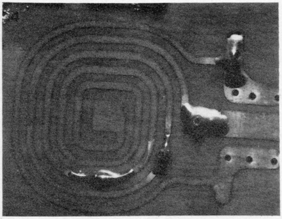
Such type of ceramic filters are found in miniature transistor radios in the I.F. Stages in both AM and FM as well as TV sets.

Quartz Crystals

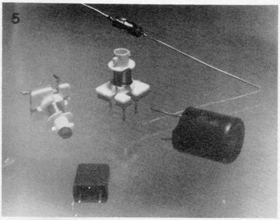
These are packed in small sheet metal cans with just two terminals coming out. Inside the can, these two terminals are connected to a quartz crystal disc. It behaves similar to the ceramic resonator. It can be excited to vibrations through AC voltage. This happens only at the resonant frequency of the crystal, which is printed on the can. The quartz crystal can be used in an oscillator circuit and gives a very precise and stable oscillator frequency. The quartz crystals are also very popular in watches and clocks in addition to their application in radio



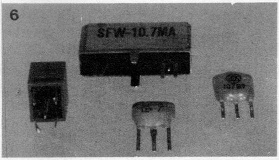
4



5



6



receivers and transmitters for giving high accuracy and stability. They are aslo used in computer circuit to generate precise clock frequencies.

Diodes

There are two types of diodes for the HF applications which differ considerably from the normal types of diodes.

The tuning diodes, are special diodes which operate in the high resistance direction. As in case of other diodes, this diode also does not allow any current in the reverse direction. However, it presents a small capacitance between anode and cathode. This capacitance changes itself with change in the blocking voltage applied across the diode. Because of this property these diodes are used in place of the rotary variable condensors in tuning circuits. A high voltage means the stator and rotor fins completely disengaged and a low voltage represents fully engaged stator and rotor fins of a rotary disc: variable condensor. In case of tuning diodes, the turning voltage can be 3 to 28 or 30 Volts, and this is adjusted by using a potentiometer. Tuning diodes are also available with voltage requirements which are less than 14 Volts. They are used in car radios and small battery operated sets.

Second type of diode specially used in HF circuit is the point contact Germanium diode. Its internal construction is shown in figure 4. Its tiny bent spring in the glass casing is even visible from outside. The tip of this spring presses on a Germanium crystal disc at the other end of the diode. This type of diode is able to rectify small AC voltages. Silicon diodes are not useful in this respect because of their higher threshold voltages. The demodulator stages of radio receivers always use Germanium diodes. However, new types of integrated circuits are being developed which will replace the needs for many discrete HF components.

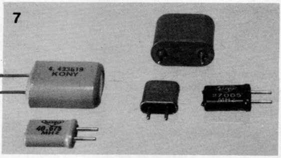
Photograph 4 :
"Printed Coil" formed by etching a spiral track pattern on a PCB.

Photograph 5 :
Variable inductance coil with ferrite core and different fixed value inductors.

Photograph 6 :
Ceramic filters for AM (455KHz), and FM (10.7MHz)

Photograph 7 :
Quart crystals in sheet metal cans.

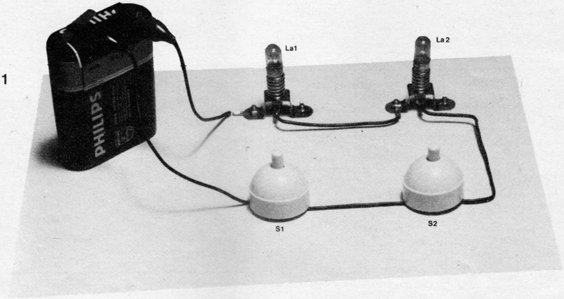
7



TWO LAMPS

AND THE ELECTRONIC TRICK

1



We have learnt a lot about electronics so far. We have also become familiar with most of the basic laws of electronics. Let us now construct an interesting circuit which will even confuse electronics experts. You can even out wit an expert by demonstrating this trick. (Of course, only if he is not also a SELEX reader himself!).

The assembled circuit is shown in figure 1. Just one look at the circuit will let anyone know that it is a series circuit having two lamps and two switches connected to a battery. However, when you demonstrate the circuit, it just behaves like a parallel circuit. A contradiction of the laws of electronics?

If switch S1 is closed lamp La1 glows and if switch S2 is closed, lamp La2 glows. What one would have expected is that both lamps would glow if and only if both S1 and S2 are closed simultaneously.

If you compare the operation of our circuit with the one shown in figure 2, you will immediately recognise that the circuit of figure 1 is functionally identical to the circuit of figure 2, a parallel circuit.

Without knowing what is inside the battery and the lamps, it is very difficult to explain how this contradictory operation of the circuit is achieved.

The trick can be demonstrated in two different ways. One way is to establish an association between S1, S2 and the sockets of La1 and La2. Other way is to establish an association between S1, S2 and the lamps La1 and La2 themselves, independent of the sockets. The second method is a bit difficult but will have amazing effects on the audience. To enhance the effect further, one can even colour the lamp La1 and Switch S1 with red and Lamp La2 and Switch S2 with green and then dramatise the demonstration by showing that the red Switch lights the red lamp in whichever socket you put it.

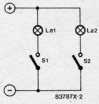
How is this possible???

In order to make this trick

Figure 1 :
The lamp trick circuit mounted on a piece of cardboard. It looks like a series circuit but behaves like a parallel circuit.

Figure 2 :
Parallel circuit with two lamps and two switches.

2



more exciting, we intended to just give the problem in this issue and the solution in the next issue. However, to avoid the excessive excitement, the solution is also given here.

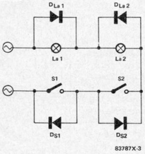
Let us see how the trick circuit functions. The principle of operation is described in figure 3. Diodes are connected in parallel to the switches and lamps. The circuit is supplied with an AC voltage. With DC supply the circuit would never function The battery shown in figure 1 is not a real DC battery but a pseudo battery which has a circuit inside it to convert the DC into AC.

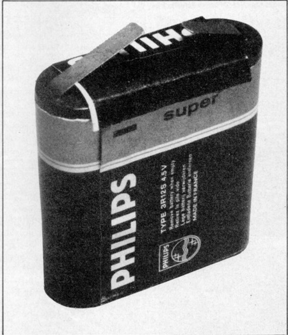
The circuit of this DC to AC converter is hidden inside the casing of the battery as shown in figure 4.

Once we know that the series circuit is really supplied with AC and not DC, and that the switches and lamps are connected with parallel diodes, it is easy to understand the functioning of the circuit.

If we close switch S1, then current flows through S1, DS2, DLa2 and La1, and the lamp La1 glows. If S2 is closed, then current flows through S2, DS1, DLa1 and La2, and the lamp La2 glows. If both switches are closed, both the lamps glow simultaneously. In reality they do not glow simultaneously but appear to glow simultaneously, because one lamp glows

3





4

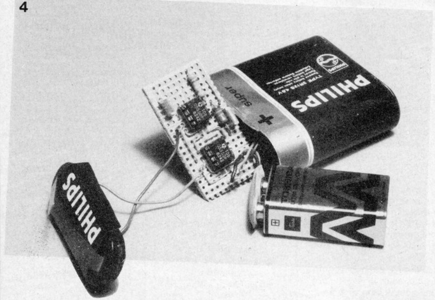


Figure 3 :
Solution of the trick circuit. It can function only with AC voltages. The diodes determine the direction of current through the circuit t during each half cycle.

Figure 4 :
The pseudo battery that produces the AC voltage but appears like a DC battery

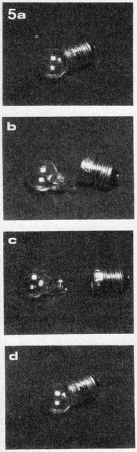
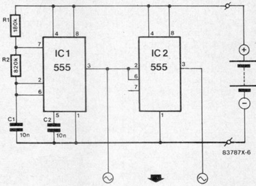


Figure 5 :
The diodes are installed inside the lamps to make them invisible. This is essential if you want to show the mysterious colour relationship between the bulbs and switches.

Figure 6 :
The DC to AC converter circuit using two timer ICs. The first IC produces a pulsating DC voltage, whereas the second one inverts this signal. Effectively there is an AC square wave between the two outputs of the ICs.

Figure 7 :
A small piece of the SELEX PCB is enough to construct the circuit shown in figure 6.

6



during the positive half cycle and other glows during the negative half cycle.

Those who want to demonstrate the trick without using coloured lamps and switches can connect the diodes behind the board on which the lamps and switches are mounted, But for those who also want to do the trick with coloured lamps and switches, it is essential that the diodes must be fitted inside the bulbs. This is a difficult job but not an impossible taks. How it is done is shown in figure 5.

In order to install the diodes inside the bulbs, the soldering tin at the soldering position of the bulbs is removed carefully. This will make the glass bulb loose from the screw cap. A twisting movement repeated a few times will be enough to take out the glass bulb. The diode can now be soldered at the two terminals and the glass bulb re-inserted into the screw cap. This is the most difficult part and must be handled very carefully, To prepare the two functional trick lamps, we may require three or four, or even more lamps depending on your skill!

The circuit of the pseudo battery which gives an AC output is constructed on a small piece of SELEX PCB as shown in figure 7. The circuit diagram is shown in figure 6. The first 555 IC is used as a multi-Vibrator and produces a pulsating DC Voltage. IC2 inverts the output signal of IC1 in such a manner, that between the two outputs of the ICs a rectangular AC voltage is produced. After constructing this circuit, it is pasted on a 9V miniature battery and then enclosed in an empty case of a larger size battery.

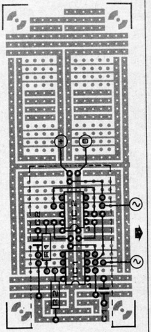
The trick circuit is constructed on a piece of cardboard as seen in figure 1 in such a manner that it very obviously looks like a series circuit.

The diodes are soldered below the switches, so as to make them invisible. If coloured lamps are used, it will be necessary to take them out from the sockets and fit them again very frequently, and in that case it is better to fix the sockets onto the board with screws using good washers.

The componemts required to construct this trick circuit are very few and the construction is simple, But the excitement it can create is amazing.

Components
R1 = 180 KΩ
R2 = 820 KΩ
C1, C2 = 10 nF
IC1, IC2 = 555
1 9V battery
1 battery clip
1 SELEX PCB
1 Empty case of a larger battery
3-4 bulbs 7V/0.1A
2 Lamp Sockets
2 Switches
1 Cardboard piece.

7



RADIO RECEIVER

We already know that radio waves travel from the radio station antenna in all directions. The antenna is nothing but an electrical conductor. To see how a radio receiver works, let us first formulate a simple law - "Whatever can be transmitted by an electrical conductor, must also be receivable by an electrical conductor". This means that for a radio receiver, the first thing we need is a piece of wire to work as an antenna and catch the radio waves.

These radio waves are high frequency waves with the audio signal superimposed on them. The high frequency carrier waves are AC in nature, so we must have a diode to first make them DC and then a capacitor to filter out the high frequency and leave only the audio frequency to drive the headphone. Figure 1 shows the simplest possible arrangement for a radio receiver. The circuit shown in figure 1 is explained in figure 2. The antenna first catches the high frequency radio waves which are AC, the diode then rectifies to produce a DC signal which has a high frequency component and a low frequency audio component. The capacitor filters the high frequency component to the ground and leaves only the low frequency audio signal to drive the headphones. The headphone converts this signal into the audio output which we can hear. Even if the capacitor was omitted, there would be an audio signal produced by the headphone, but it won't be as pure as what we have with the capacitor.

All this is true only for the AM type of radio waves, which are Amplitude Modulated. In case of FM type of radio waves, which are Frequency Modulated, just a diode and capacitor does not work and a more complex demodulator circuit must be used.

The simple receiver shown in figure 1 can practically function only in very close vicinity of a powerful radio station, with AM transmission in Long Wave, Medium Wave or Short Wave. However, if more than one transmitter is present in the vicinity, our circuit can make no distinction between them and will produce a mixture of both the signals — two programs will come out of the headphones simultaneously.

As the circuit does not have a power source of its own, signals from far away stations cannot be reproduced through the headphones because the signal strength is not enough to drive the headphones. Our simple circuit has no selectivity, neither sensitivity.

Let us first see how we can achieve the desired selectivity, so that we can distinguish between two transmitters. Figure 3 shows a modified circuit which has an additional capacitor and an inductor. This is a parallel resonant circuit. This behaves like a short circuit to ground, for unwanted signals and behaves like an open circuit to the signal to which it is tuned. Thus we can select the desired frequency by tuning the circuit by using the variable capacitor.

The antenna catches all the radio waves which reach it and a current tries to flow through the inductor coil and the parallel capacitor to ground.

The property of the parallel resonant circuit is that it provides a very high impedance to the signals which have the frequency to which the circuit is tuned. Thus only the radio waves having that particular frequency can pass through the diode to the headphones. All other radio waves can directly pass to the ground through the inductor coil.

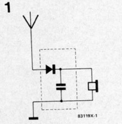
This allows us to select the radio station of our choice, just by adjusting the variable capacitor in the parallel resonant circuit. With the circuit of figure 3, we have solved the problem of selectivity to a certain

Figure 1 :
The simple M W receiver consisting of the antenna, the detector diode and headphone.

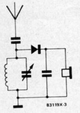
Figure 2 :
The functioning of the simple receiver. The diode converts the signal to DC. The capacitor filters out the high frequency part. The Audio Frequency modulation signal finally remains for driving the headphone.

Figure 3 :
If the antenna receives more than one transmitter signals, we must be able to select only one of them at a time. The input tuning circuit consists of an inductor coil and a parallel capacitor, which form a parallel resonant circuit.

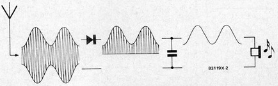
1



3



2



extent. However, even this circuit will not be able to receive a far away station. Because we still do not have the required sensitivity to get the weak signals to drive our headphones.

This can be achieved by using an amplifier stage between the parallel resonant circuit and the detector diode, as shown in figure 4. The amplifier A amplifies the high frequency carrier waves before they reach the demodulating circuit. But an amplifier needs a battery to function and our circuit can no longer work by drawing power from the radio waves. As we have an amplifier in the circuit, it is possible to receive even far away stations. However, this once again poses a problem of selectivity because even other signals which have frequency values nearer to the tuned frequency can also now be amplified sufficiently to drive the headphones. This calls for one more tuning circuit after the amplifier, as shown in figure 5.

We can continue in this manner and go on increasing sensitivity and selectivity. But a problem with this approach is that for best results, all of these tuned circuits must be tuned equally for every different radio station we want to receive. To overcome this problem, an ingenious method is used The tuning is done only in the first stage for the desired station and then that frequency is converted to a fixed intermediate frequency in the next stage. (called the Mixer stage). The remaining stages are all tuned only once during the construction of the circuit to the intermediate frequency and need not be retuned for every different radio station. This type of radio receivers are called Superheterodyne Receivers.

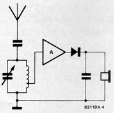
The most important part of this 'Superhet' receiver is the mixer stage which produces the intermediate frequency signal (I.F. signal) for the remaining part of the circuit, independent of the frequency of the radio station tuned in by the tuning circuit of the receiver. What the mixer does is that, using a variable capacitor which is physically ganged with the tuning capacitor, it drives an oscillator to produce a frequency which is exactly 455 KHz more than the resonant frequency of the tuning circuit. This oscillator frequency is then mixed with the signal received from the radio station. As the oscillator frequency always remains ahead of the radio station frequency by 455 KHz, the output of the mixer stage has always the same frequency of 455 KHz. The audio signal is still super-imposed on this new carrier wave of 455 KHz.

Figure 6 shows the simplified circuit of a Superhet receiver. The tuning circuit has a range of 500 to 1600 KHz (MW range). The oscillator is so designed as to have a range of 955 KHz corresponding to the tuning circuit range.

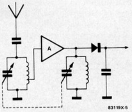
If the tuning circuit is tuned to 500 KHz, the oscillator has frequency of 955 KHz. When these two signals are fed to the mixer, it gives an output with a frequency of 455 KHz. If we now move the tuning knob further till the receiver is tuned to 1000 KHz, the oscillator automatically changes its oscillation frequency to 1455 KHz. The difference is once again 455 KHz and the mixer output still remains at 455 KHz. The remaining part of the receiver never knows the actual frequency of the radio station to which we have tuned our receiver. From the output of the mixer stage onwards, the receiver works as if we have tuned to only one radio station having a carrier frequency of 455 KHz. This is why the remaining tuned stages are called I.F. stages.

To improve upon the performance, we can even use more than one Superhet stages. The output of the I.F. stages can once again be passed through a pair of oscillator and mixer to produce a second Intermediate Frequency. This is called a double Superhet. One can even have a triple Superhet!

4



5



6

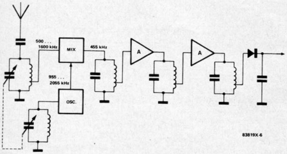


Figure 4 :
An RF amplifier stage improves the sensitivity of the simple receiver circuit.

Figure 5 :
Additional tuning circuit introduced to improve the selectivity. This uses a double rotary disk condensor.

Figure 6 :
The simplified circuit diagram of a 'Superhet' receiver. The antenna signal is mixed with the oscillator signal in the mixer stage to produce a fixed frequency output of 455 KHz. The oscillator is so designed that it always produces a frequency which is ahead of the frequency of the antenna signal just by 455 KHz. This frequency is known as the Intermediate Frequency (I.F.). The subsequent stages are tuned to this frequency.

DIGITAL THERMOMETER

Economy has introduced a portable instrument for measuring temperatures. The Units are provided with dry batteries and are intended for use with K-type thermocouples. Temperature range is -50 to - 1200 C.

Fo further details contact:—
ECONOMY ELECTRONICS
15, Sweet Home
442, Pitambar Lane
Off Tulsi Pipe Road,
Mahim, Bombay-400016

CNC WINDING MACHINE

Tazac 90 series machines are meant for high volume production. The main features 3 axes control, adding optional facilities like wire cutting, soldering, and unloading, easy to use key board for programmes of your specs.

The speed of the machine can be as high as 1000 rpm ensuring high volume production. The programming is very simple requiring only 5-6 hours to familiarise oneself with the method. The machine is provided with all the standard accessories like flyers and bobbin support devices (can be changed according to the wire size) The winding jigs can also be supplied with the machine after receipt of details of winding and samples.

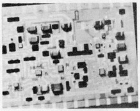
For further details contact:
MURUGAPPA ELECTRONICS LTD
Agency Divn
Parry House III floor
43 Moore Street
Madras 600 001.

HYBRID MICRO CIRCUITS

VHEL offers thick film hybrid micro circuits to manufacturers of professional electronic equipment, computers, telecommunications, instrumentations & control electronics and medical electronics.

VHEL's service starts with detailing of hybrid layouts on customer circuits, bread boarding & concept testing, if needed, prototyping, manufacturing and supply. VHEL state that they can meet MIL 883B & ISHM standards for the process & performance.

VHEL can supply circuits from the facilities of its collaborator SCRANTOM ENGINEERING INC., U.S.A. after completion of applications engineering for the user in India by VHEL engineers.



For further details please contact:

M/S VIKAS HYBRIDS & ELECTRONICS LTD.
B-433, New Friends Colony,
New Delhi-110 065

TEMPERATURE SELECTABLE SOLDERING STATION

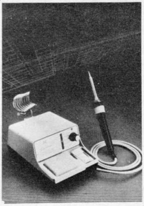
The SUPERTEMP XY7 soldering stations offer controlled temperature hand soldering. 320°C, 350°C, 380°C, 410°C and 440°C fixed temperatures are selectable by rotating the switch.

The insulated NICHROME wire heating element is compressed between two layers of stainless steel and is located at the end of the barrelto ensure instant heat up and recovery.

An electronic control circuit maintains tip temperature to within ±3°C (6 F). This is accomplished by embedding the thermocouple sensing unit in the bevel of the heating element barrel so that the tip actually seats against it. This method allows the closest possible monitoring of tip working surface temperature.

The electronic "Zero Voltage" switching protects voltage and current sensitive devices such as CMOS, against transient voltage spikes caused in stations.

The soldering tip is grounded through the power unit to ensure the tip leakage to less than 0.4 millivolt or 0.03 microampere.



Available from:
DAVLE TECH INC.
2-05 Banta Place, Fair Lawn,
New Jersey 07410, U.S.A.
Tel: (201) 796-1720

MAKE-YOUR-OWN TV KIT

Taurus Electronics has introduced 14" B & W MAKE-YOUR-OWN TV Kit Model 14220. It is a low priced SKD Kit with cabinet, Picture Tube, all accessories packed in a carton. The kit is pre-aligned with built in connectors. The unit has a highly sensitive VHF Tuner with Channel Coverage 2-12 and gain at 60 db. It has a unique quick heat type picture system. Only BEL make picture tubes are given inthe kits. The Peak Autio output is 2 W with an earphone jack for private listening. The TV when assembled works on Ac 220 50 HZ, consumes 10 W power The TV also works on 12 V DC adopter. A VCR sockt is provided for VCR viewing. The indoor antenna with the kit dispenses the necessity for installing an external antenna in a HPT zone. This kit is also guaranteed.

For further details, contact:
HARESH G. NATHANI,
TAURUS ELECTRONICS,
13, Bussa Udyog Bhavan,
Lower Ground Floor,
T.J. Road, Sewree (W)
near Sewree Bus Terminal,
Bombay - 400 015

TACHOGENERATOR

Advani-Oerlikon have added a new Techogenerator, Model : DTG-P-143-0 to their range of power control equipment. This version gives minimum deviation from the linearity, Minimum ripple in the output voltage, close tolerance regulation and better-performance at lower speeds. It is tailormade to suit operation conditions in various industrial applications. It is Designed for speed indication and feedback control of DC variable speed drives.

The equipment can be flange and/or foot mounted. Special temperature compensation for output voltage can be provided upto 90°C. Also voltage-to speed ratio can be adjusted as per customers requirements.

For more details, quote ref. No. P19/7/84 and write to:
Advani—Oerlikon Limited
Post Box No. 1546
Bombay 400 001.

P C B COATING

CRC Acryform is now manufactured in India under a technical license agreement with world renowned CRC Chemicals, Europe.

CRC Acryform is a fast drying, single component conformal coating for application on printed circuit assemblies. Having very good solderability and excellent flexibility, CRC Acryform protects assembled PCB's from humidity, fungus and corrosion. The coating provides insulation against high voltage arcing and corona shorts. It is excellent from production standpoint as it is easy to apply, has a long shelf life (2 years), and is easy to remove if rework becomes necessary. CRC Acryform is easy to handle with a dry to touch time (air drying) of 30 minutes. As CRC Acryform is transparent, coated components are easily identified. Single components may be replaced by soldering or desoldering directly through the coating.

The cured film can be removed by using chlorinated solvents such as methylene chloride or trichloroethane.

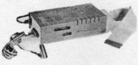
For further details, please contact Acryform Division:

BHARAT BIJLEE LTD.
Electric Mansion, 6th Floor
Appasaheb Marathe Marg
Prabhadevi
Bombay 400 025

ICE FOR 8 BIT μPs

Advanced Electronic Systems introduce their model ICE-8 which features

- * Fully buffered data, address and control signals to the target
- * No restrictions on the target processor's memory and I/O space
- * 8K emulation memory can be mapped into any 8K block in target memory range
- * Break points with loop count
- * I/O ports can be polled upto 256 times with sampling duration adjustable from 1 to 256 m secs.
- * Resident assembler and two-pass dis-assembler
- * Upload/down load facility for executable files to/from a host computer system (like IBM PC)

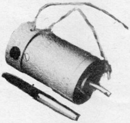


For further details contact:

ADVANCED ELECTRONIC SYSTEMS
106, 8th Main, Malleswaram
West, Bangalore 560 055

MOTORS

MAGNA MOTORS introduce permanent magnet motors of voltage ranges 12 to 110 volts speeds 1500 to 8000 RPM, and wattages upto 250 watts. These motors find applications in Switchgear units as charging motor for Oil/Air/Vacuum Circuit breakers, isolators, welding machines, lab equipments, Business machines, electronics telecommunications and domestic appliances with intermittent and semi continuous duty cycle.



For further details contact:

MAGNA – MOTORS
No.88A/3, (204), 3rd Cross
IInd Main Prakashnagar
Bangalore 560 021

PROM PROGRAMMER

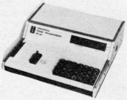
Professional Electronic Products introduce their Universal PROM Programmer PP-85.

PP-85 eliminates the Connection Adapter' approach; the selection of the PROM type is through a command. PP-85 has 32 K bytes of internal data RAM to program 32 K 8 byte 27256 EPROM. The PP-85 basic unit contains all the hardware and software to program the range of EPROMs from 2716 (2 Kx8) to 27512 (64K x8) EPROM. Besides it can also program a number of EEPROMs. Wherever applicable intelligent programming algorithms have been used to reduce the programming time.

PP-85 has LED display and a key board for entering the command and data. In addition, an Rs 232C serial I/O port is provided for down loading the data from a computer or an MDS. Software is available at present to interface PP-85 with IBM PC compatible computer.

Separate Programming Modules are also available for the following:

1. Gang programming Module: Programs 8 NMOS EPROMs at a time.
2. Microcontroller programming Module: Programs 8741, 8742, 8748, 8749, 8751 & 8755.
3. Bipolar PROM Programming Module: Programs nearly all Signetics, T1 (Texas Instrument), NS (National Semiconductor) and AMD (Advance Micro Device) bipolar PROMs.
4. PAL Programming Module: for popular PALS (Programmable Logic Arrays).

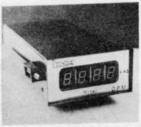


For further details contact:

PROFESSIONAL ELECTRONIC PRODUCTS
Opp. Old Octroi Post, Delhi Road, Meerut 250 007, U.P.

AUTO RANGE PANEL METER

PRESTIGE ELECTRONICS introduce their Autoranging digital Panel Meter Display is 3½ Digit 12.5mm Red, Green or Yellow. Range selection is automatic depending on input voltage. Ranges are 1.999V, 19.99V, 199.9V & 750V DC overall accuracy is 0.25% ± 1 Digit for DC & 0.7% ± 1 Digit for AC models. Dimensions are 48 x 96 x 190mm (½ Din size) Cutout 45 x 96mm. Input supply is 230V ± 10%.



For further details contact:

PRESTIGE ELECTRONICS
62/A, Pushpa Park, Malad (E)
Bombay 400 097
Tel: 693805

classified ads

8085 MICROPROCESSOR TRAINER built in EPROM programmer, power supply, 2K CMOS/RAM with dry cell back up expandable to 8 K, 12 K user EPROM installed Rs. 2975/- All inclusive.
EPROM Eraser Rs. 500/- Contact: NEW AGE ELECTRONICS, Third Floor, Laxmi Mahal, Near Vandana Cinema, Agra Road, Thane - 400 602.

Attention ZX-SPECTRUM users: Superb programmes available for tape back-up copies, Games and utilities, Write to: M.S. Bhatnagar, 45-A, Pologround, Udaipur-313 001.

For sale : HM 312, Dual Trace, 20 MHz Scientific Oscilloscopes with Component Tester and 3½ digit ZE 1501 Zenith Benchtop DMM in perfect working condition, Contact: M.M. Corporation. Tel: 492 1143.

Wanted Diploma Electronics Engineer with minimum 1 year experience for testing and servicing Analog and CMOS Digital modular circuits of European machines. Apply immediately to M.M. CORPORATION 3/319 Sun Industrial Estate, Lower Parel, Bombay 400 013

CORRECTIONS

D-A converter for I/O bus

January 1987 p. 1-21

In Fig. 3, the order of the databits D_0-D_7 should be reversed both at the bus connector and the inputs of IC_1.

Universal control for stepper motors

Feburary 1987 p. 2-31

Table 5a should be amended as follows: M21 = $5D_h$. In Table 5b, the databyte at M3E should read 00_h.

advertisers index

R.N. No. 39881/83 Allowed to Post without prepayment LIC No. 91 MH/BY WEST – 228
LIC No 91

Damle

Printer & Publisher – C.R. Chandarana, 2, Koumari, 14th A Road, Khar, Bombay 400 052.
Printed at Trupti Offset, 103 Vasan Udyog Bhavan, Tulsi Pipe Road, Lower Parel, Bombay 400 013.